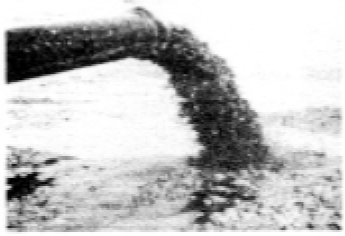
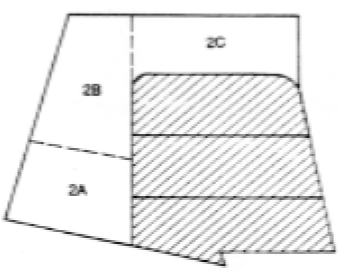
US Army Corps of Engineers





ALTERNATIVE 2

ENVIRONMENTAL LABORATORY

TECHNICAL REPORT EL-89-6

STORAGE CAPACITY EVALUATION FOR CRANEY ISLAND EXPANSION ALTERNATIVES

by

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Environmental Laboratory

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Since the 1950s the Craney Island disposal facility has been used for containment of dredged material from the navigable channels and harbors of Hampton Roads, VA. The site has annually received between 3 million and 4 million cu m of maintenance dredged material. The existing site, which was subdivided into three compartments in 1984, is nearing maximum capacity. Therefore, the US Army Engineer District, Norfolk, initiated studies to evaluate potential expansion alternatives in an effort to identify the alternative that will maximize existing storage capacity (and provide approximately 50 years of additional storage capacity) while minimizing environmental impacts.

This study is one of three concurrent studies to evaluate various aspects of the expansion alternatives. The focus of this study was the volumetric storage capacity of each alternative, while the other studies evaluated separately (a) the hydrodynamic impacts of

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Confined disposal	Disposal life	Site capacity
Consolidation	Dredged material	Storage capacity
Craney Island	Dredging	
Disposal	Expansion alternatives	

19. ABSTRACT (Continued).

each expansion alternative on the flow regime in the Hampton Roads area and (b) the geotechnical feasibility of constructing retaining dikes for each alternative.

The storage capacity, and thus the remaining active disposal life, of the existing Craney Island facility was determined as well as that of each expansion alternative, both with and without considering the existing facility. The scenarios were evaluated assuming an active dewatering program. The influence of subdividing the expansion facility into multiple compartments was also evaluated.

The available dredged material storage capacity of each configuration was subsequently calculated from considerations of dike volume requirements. The filling history of each configuration was simulated with the computer program Primary Consolidation and Desiccation of Dredged Fill. Input requirements necessitated compilation of the consolidation characteristics of the foundation soil and dredged material as well as the appropriate values to simulate site dewatering. The active disposal life of each facility was ultimately determined from the filling simulations and anticipated maximum dike heights.

PREFACE

This report was prepared by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES), for the US Army Engineer District (USAED), Norfolk. Funding was authorized by Intra-Army Order No. (IAO) BB-87-3011, 20 April 1988, and IAO BB-88-3001, 13 October 1988.

The report was prepared by Dr. Marian E. Poindexter-Rollings, under the general supervision of Dr. John J. Ingram, Chief, Water Resources Engineering Group (WREG), EL; Dr. Raymond L. Montgomery, Chief, Environmental Engineering Division (EED), EL; and Dr. John Harrison, Chief, EL. Acknowledgment is made to Mr. Mark Howard, WREG, for his assistance in computer program modification and initial data reduction; to Mr. Thomas E. Schaefer, WREG, for his assistance in creating the numerous computer input data files and making the computer runs; and to Mrs. Cheryl M. Lloyd and Mr. Anthony Gibson, WREG, for tabulating and plotting the output data. Technical review was provided by Dr. Ingram and Dr. Michael R. Palermo, EED. The report was edited by Mrs. Jessica S. Ruff of the WES Information Technology Laboratory.

Operational considerations, including schedules for dredging and disposal and projected quantities of sediment to be dredged, were provided by numerous personnel of the USAED, Norfolk, with the major input coming from the Engineering and Planning Divisions.

Commander and Director of WES was COL Dwayne G. Lee, EN. Technical Director was Dr. Robert W. Whalin.

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CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
pounds (force) per square foot	47.88026	pascals

STORAGE CAPACITY EVALUATION FOR CRANEY ISLAND EXPANSION ALTERNATIVES

PART I: INTRODUCTION

Background

1. Craney Island is a 2500-acre* dredged material containment facility located in Portsmouth, VA, adjacent to the harbor of the Hampton Roads area. As shown in Figure 1, it is located at the confluence of the James and Elizabeth Rivers. Planning for this facility began in the early 1940s when a need was identified for a long-term disposal site to receive materials dredged from the navigation channels and berthing areas in Hampton Roads. The facility was designed to (a) provide sufficient storage volume for dredged material during the design life of the facility and (b) provide adequate sedimentation of dredged material solids to maintain acceptable effluent water quality.

2. Actual work on the Craney Island facility began in August 1954 with construction of the confining dikes. After 2-1/2 years, construction was completed in January 1957. Since that time, the dikes have been raised incrementally to elevations between +26.0 and +33.0 mlw. Construction of two interior dikes was completed in 1984 and effectively separated the disposal area into three subcontainments, or cells, of approximately equal size. Construction of the interior dikes was begun prior to 1980 and was accomplished across one half to one third of the disposal facility using debris and end-dumped sand as fill material. Completion of the two interior dikes was accomplished in 1984, using geotextiles under the diking material to effectively float the dike across the soft dredged material. Although the initial portions of the interior dikes were built to help prevent short circuiting, they were completed for the express purpose of separating the site into individual compartments for management purposes.

3. The need to actively manage the Craney Island facility was recognized as the site began to fill and the need to identify future disposal sites was anticipated. Because of concern in the Norfolk District about disposal

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

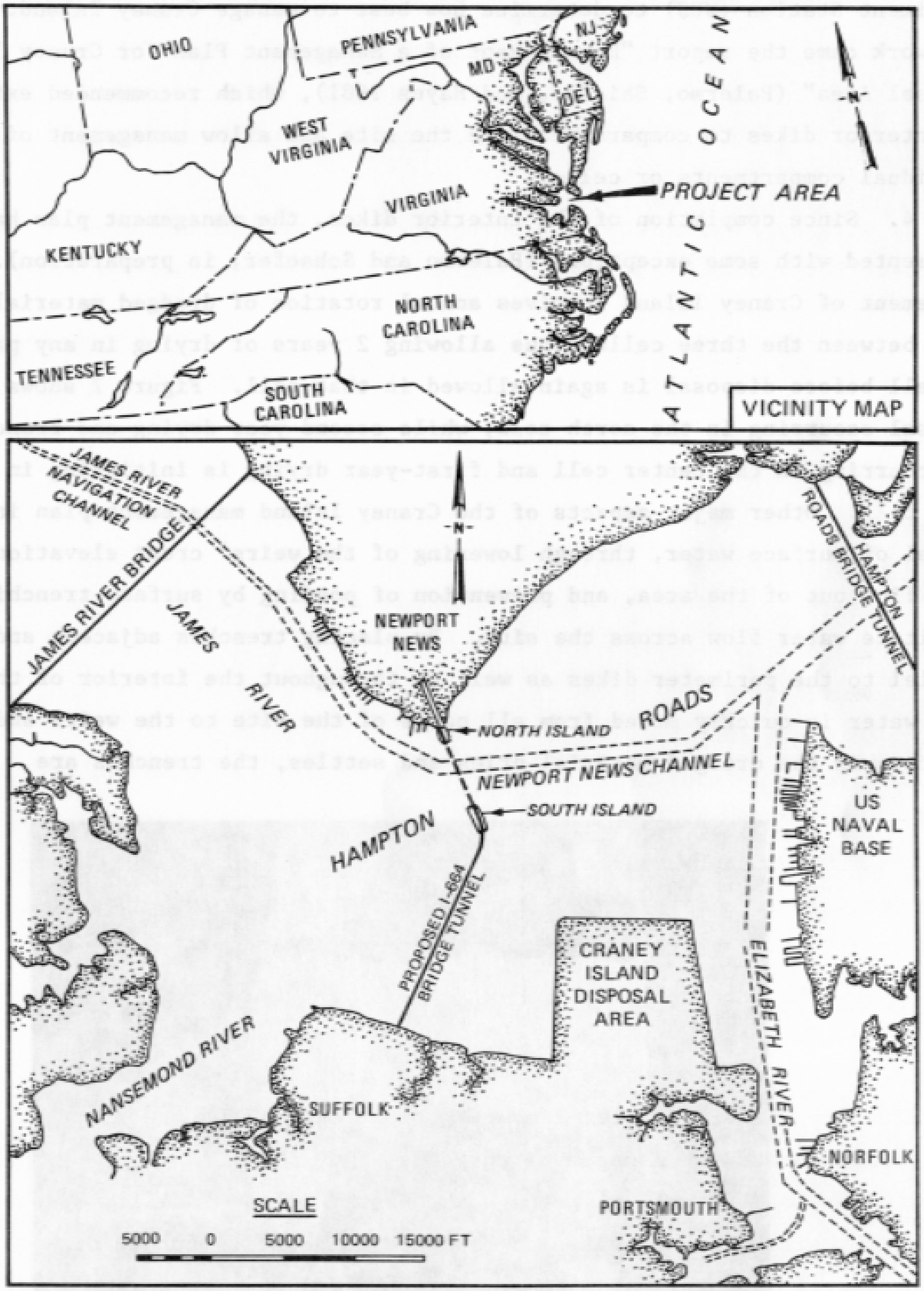

Figure 1. Craney Island project location

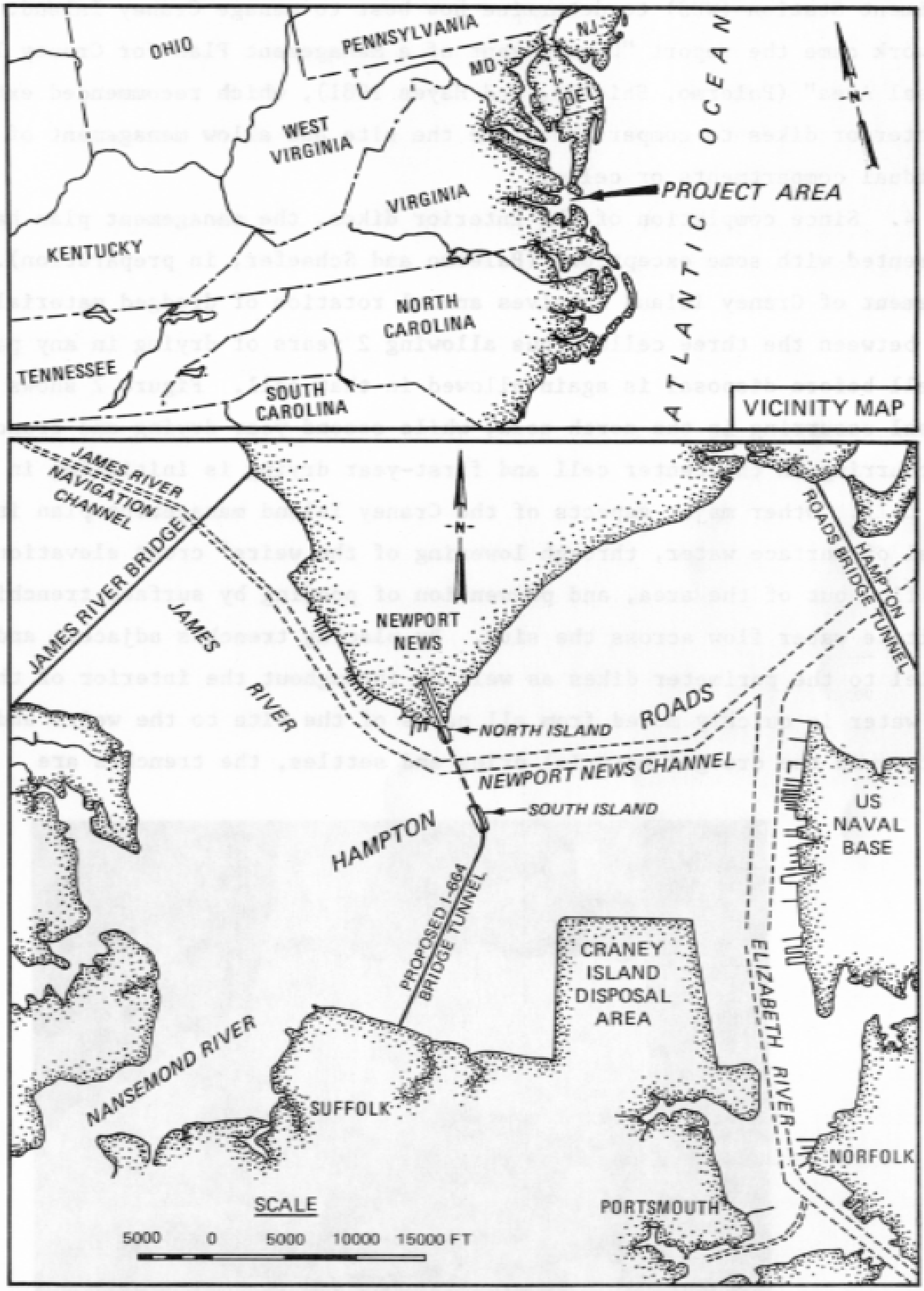

Figure 1. Craney Island project location

area management and operation to maximize the useful life of Craney Island, the Norfolk District funded an investigation by the US Army Engineer Waterways Experiment Station (WES) to determine how best to manage Craney Island. From this work came the report "Development of a Management Plan for Craney Island Disposal Area" (Palermo, Shields, and Hayes 1981), which recommended extending the interior dikes to compartmentalize the site and allow management of the individual compartments or cells.

4. Since completion of the interior dikes, the management plan has been implemented with some exceptions (Palermo and Schaefer, in preparation). The management of Craney Island involves annual rotation of dredged material disposal between the three cells, thus allowing 2 years of drying in any particular cell before disposal is again allowed in that cell. Figure 2 shows active disposal occurring in the north cell, while second-year drying and trenching are occurring in the center cell and first-year drying is initiating in the south cell. Other major aspects of the Craney Island management plan include removal of surface water, through lowering of the weirs' crest elevations to allow flow out of the area, and prevention of ponding by surface trenching to facilitate water flow across the site. By placing trenches adjacent and parallel to the perimeter dikes as well as throughout the interior of the site, water is quickly moved from all parts of the site to the weirs and then offsite. As the dredged material dries and settles, the trenches are

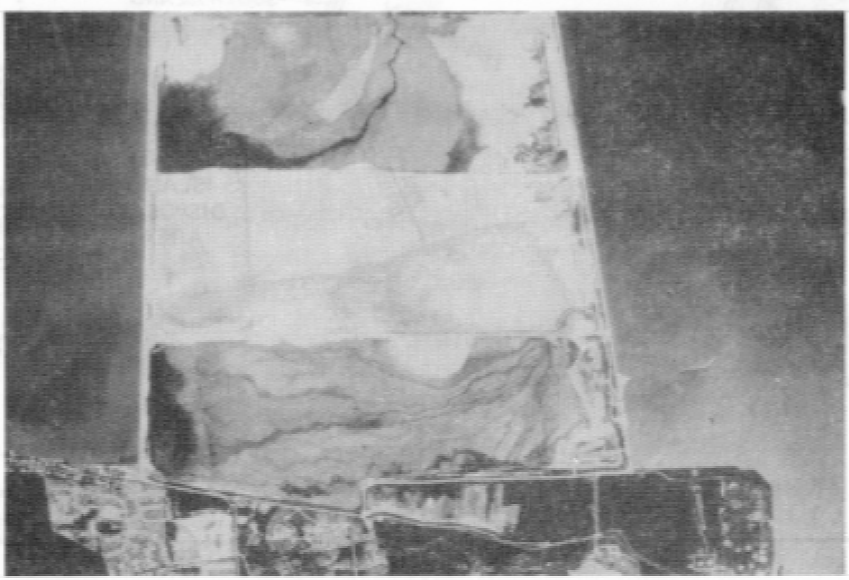

Figure 2. Existing Craney Island facility, after subdivision into three compartments

progressively deepened; thus, the term "progressive trenching" is applied to this operation. The management plan also calls for (a) installation of instrumentation during inactive (drying) periods and monitoring and (b) removal of coarse-grained and dry fine-grained material.

5. Through implementation of the Craney Island management plan under the authority of Section 148 of Public Law (PL) 94-587, much of the 4 to 5 million cubic yards of fine-grained material placed annually into Craney Island has been significantly dewatered. As a result, the useful life of the site has been extended. Despite this fact, the planned harbor deepening around Hampton Roads will result in placement of additional dredged material in Craney Island, which will reduce considerably the active life of the site. Therefore, an alternative disposal site must be located.

6. Because acquiring new dredged material disposal sites in the vicinity of Hampton Roads would be difficult, the Norfolk District has determined that expansion of the existing Craney Island facility is a practicable alternative. Six potential expansion configurations have been identified and are being evaluated for their hydraulic, geotechnical, and containment capacity feasibility. The latter evaluation is the subject of this report, while the former two evaluations were conducted concurrently by the Hydraulics and Geotechnical Laboratories, respectively, of the WES (Heltzel 1986, Spigolon and Fowler 1987).

Objectives

7. The objective of this work was to determine the active dredged material disposal life and the storage capacity of the existing Craney Island facility, as well as that of each expansion alternative both with and without the existing facility. The various scenarios were evaluated assuming an active dewatering/management program. The influence of subdividing the expansion facility into two or three subcontainments was also evaluated.

Scope of Work

8. To meet the project objectives, several associated tasks were performed. Initially, the physical dimensions of each of the six alternative

configurations were determined from large-scale (1:20,000) bathymetric maps, discussions with Norfolk District personnel, and coordination with the hydrodynamic and geotechnical engineering analyses conducted concurrently at WES. The available dredged material storage capacity of each configuration was subsequently calculated accounting for dike volume requirements. The filling history of each configuration was simulated with the computer program Primary Consolidation and Desiccation of Dredged Fill (PCDDF). Input requirements necessitated the compilation of the consolidation characteristics of the foundation soil and dredged material as well as the appropriate values to simulate site dewatering. The active disposal life of each facility was ultimately determined from the filling simulations and anticipated maximum dike heights.

PART II: HISTORICAL AND FUTURE DREDGING AND DISPOSAL REQUIREMENTS FOR HAMPTON ROADS

9. The Hampton Roads area of Virginia is a heavily populated region along the eastern coast of the United States. It is located on the James River near the mouth of the Chesapeake Bay. The Hampton Roads Harbor is surrounded by several cities, including Norfolk, Portsmouth, Newport News, and Hampton, with Virginia Beach, Chesapeake, Suffolk, and Poquoson also in the vicinity. Not only are there significant industrial developments and population centers in the area, but Norfolk is home to the North Atlantic Fleet of the United States Navy.

10. With the significant amount of waterborne commercial traffic through Hampton Roads, as well as the large water-related defense contingent, there has been an historic need to maintain the navigable waterways of the area. Therefore, throughout recent history, large quantities of sediment have been dredged from the waters of Hampton Roads; associated with dredging is the requirement to dispose of the material in an approved disposal site. Because of the large quantity of material dredged annually, a large disposal site capacity has been and will continue to be required in Hampton Roads.

Historical Requirements

11. Craney Island is a 2,500-acre confined disposal facility that is used to contain dredged material. It is by far the largest disposal facility in the Hampton Roads area and has historically been used to contain most sediments dredged from the area. This includes material from the Norfolk Harbor entrance channel, the Southern Branch navigation channel in the Elizabeth River, and the Newport News navigation channel, as well as numerous turning basins, anchorages, and piers.

12. Much of the dredging has been conducted by the Norfolk District, although significant portions of the material have been dredged by other Federal agencies, especially the Navy, and by private firms. Most of the dredging that occurred between 1956 and 1987 has involved maintenance work, although periodic new work dredging has been accomplished during channel widenings and deepenings and for development of new berthing areas. A summary of the sources, quantities, and times of placement of dredged material into

Craney Island is given in Appendix A. On the average, approximately 5 million cubic yards of material has been placed into Craney Island annually.

13. From completion of construction of Craney Island in 1956 until closure of the interior cross dikes in 1984, the entire site was operated as one large containment cell. Dredged material was normally pumped into the site along the eastern dike, and clarified effluent was released from weirs along the western dike. Since dredged material was almost continuously being pumped into Craney Island, the site was usually inundated with water, and no drying of the dredged material surface could occur.

14. Completion of the interior dikes in 1984 resulted in formation of three separate cells at Craney Island. Each cell has been operated independently of the others since that time. Disposal operations have generally been rotated through the three cells on an annual basis. The rotation sequence has been north cell, center cell, and south cell, with disposal in 1987 occurring into the south cell. By rotating disposal operations, 1 year of active disposal followed by 2 years of drying has generally occurred in each cell.

Future Requirements

15. With implementation of the Federal navigation channel deepening, which is authorized under the 1986 Water Resources Development Act (PL 99-662), dredging requirements in Hampton Roads will increase significantly for the near future. The channel deepening is currently scheduled for incremental completion. Initial stages began in fiscal year (FY) 1987, and final stages will end in FY 1999. The sequence of channel deepening is scheduled as follows: (a) the outbound Norfolk Harbor entrance channel to a depth of 50 ft (designated "50OB"), (b) the outbound entrance channel to a depth of 55 ft (55OB), (c) the Southern Branch channel of the Elizabeth River to a depth of 45 ft (SB45), (d) the upstream portion of the Southern Branch to a depth of 40 ft (SB40), (e) the inbound Norfolk entrance channel to a depth of 50 ft (50IB), and (f) the inbound entrance channel to a depth of 55 ft (55IB).

16. With each stage of the deepening project, significant quantities of new work material will be dredged and will require disposal. As the deepening project progresses, the quantity of maintenance material to be dredged annually is also expected to increase. Table 1 summarizes the quantities of sediment to be dredged in the future. These quantities are, of necessity,

estimates that were developed by the Norfolk District and are based upon past experience, hydraulic modeling results, and best estimates of future conditions.

PART III: POTENTIAL EXPANSION SITES

17. Six potential expansion sites had previously been identified by Norfolk District personnel (see Figure 3). Each of these sites abutted the existing facility on the north or west side, or both. Expansion to the east was impossible because of the proximity of the Elizabeth River ship channel; to the south was located prime residential land. Thus, expansion possibilities were limited to the west and north.

Expansion Site Conditions

18. The initial task was to establish the initial water depths and diking configurations before determining the spatial dimensions of the alternative configurations for the expansion facility. The locations of the end points for each dike were obtained from the bay hydrodynamic study conducted as part of the overall expansion analysis (Heltzel 1986). Dike lengths and mean water depths were determined from the 1:20,000-scale National Oceanic and Atmospheric Administration bathymetric chart for Hampton Roads. Depths were adjusted to a common datum, as necessary, on the basis of a 1.5-ft differential between mean low water and mean sea level.*

19. The total volume available for dredged material storage within each configuration was influenced by the volumetric requirements of the perimeter and interior dikes. Preliminary information concerning the side slopes and crest dimensions and elevations were obtained from the associated geotechnical engineering study conducted for the expansion project and from a previous WES study (Palermo, Shields, and Hayes 1981; Spigolon and Fowler 1987). For perimeter dike construction in shallow water, i.e., less than 15 ft deep, a side slope of 1 ft vertical to 30 ft horizontal (1:30) will generally ensure slope stability. The greater depths of water encountered in the northern sections of Alternatives 1, 2, and 3 will require a more shallow side slope to maintain slope stability. An average slope of 1:80 was used for these perimeter dikes in the storage capacity calculations. A transition slope of 1:15 was assumed between el −2.0 mlw and el +4.0 mlw, while a slope of 1:2 was

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* Personal Communication, 1986, Tom Szelest, US Army Engineer District, Norfolk, Norfolk, VA.

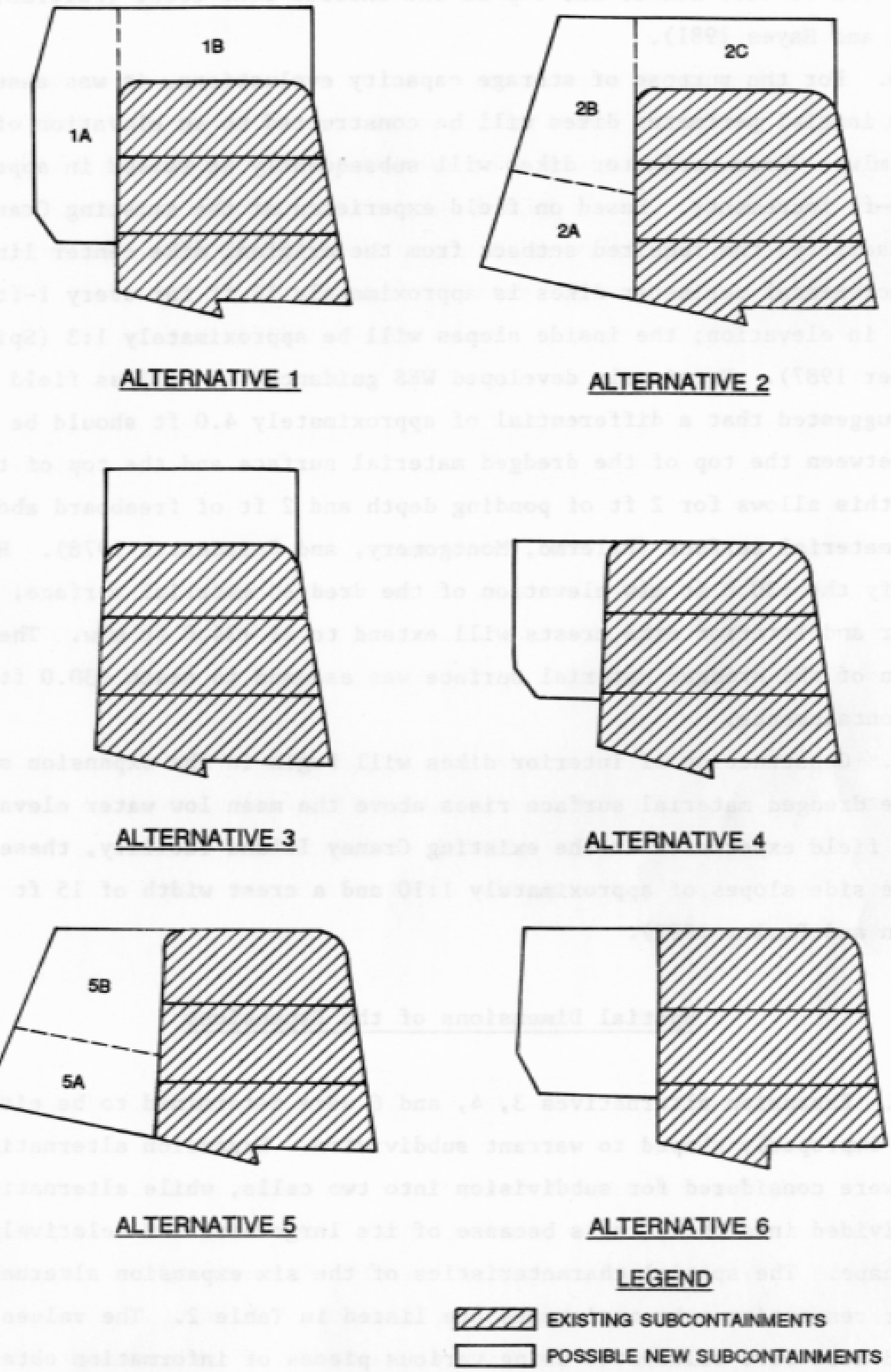

Figure 3. Alternative configurations for expansion of Craney Island

assumed from el +4.0 mlw to the top of the initial dike crest (Palermo, Shields, and Hayes 1981).

20. For the purpose of storage capacity evaluations, it was assumed that the initial perimeter dikes will be constructed to an elevation of +8.0 ft mlw. These perimeter dikes will subsequently be raised in approximately 8-ft increments. Based on field experience at the existing Craney Island facility, the required setback from the original dike center line for these incremental perimeter dikes is approximately 14 ft for every 1-ft increase in elevation; the inside slopes will be approximately 1:3 (Spigolon and Fowler 1987). Previously developed WES guidance, as well as field experience, suggested that a differential of approximately 4.0 ft should be maintained between the top of the dredged material surface and the top of the dike crests; this allows for 2 ft of ponding depth and 2 ft of freeboard above the dredged material surface (Palermo, Montgomery, and Poindexter 1978). Hence, to satisfy the +30.0 ft mlw elevation of the dredged material surface, the perimeter and interior dike crests will extend to el +34.0 ft mlw. The final elevation of the dredged material surface was assumed to reach +30.0 ft mlw in all subcontainments.

21. Construction of interior dikes will begin in the expansion sites after the dredged material surface rises above the mean low water elevation. Based on field experience at the existing Craney Island facility, these dikes will have side slopes of approximately 1:10 and a crest width of 15 ft (Spigolon and Fowler 1987).

Spatial Dimensions of the Expansions

22. Expansion alternatives 3, 4, and 6 were determined to be either too small or improperly shaped to warrant subdivision. Expansion alternatives 1 and 5 were considered for subdivision into two cells, while alternative 2 was subdivided into three cells because of its large size and relatively narrow shape. The spatial characteristics of the six expansion alternatives and their respective subcontainments are listed in Table 2. The values tabulated here were calculated using various pieces of information obtained from several sources: hydrographic survey maps, previously published reports, concurrent studies of the Hampton Roads area, and written and verbal communications with Norfolk District personnel. The entries in Table 2 are

arranged according to the projected disposal periods. The initial line of values for each alternative is associated with the initial perimeter dike construction to el +8 mlw, i.e., when the dredged material surface is below el +4.0 ft mlw. Directly below that line are additional lines of values corresponding to subsequent disposal periods when the dredged material surface will increase from el +4.0 mlw to el +30.0 mlw; one additional line is presented for each cell of each expansion alternative. The average bottom elevations presented in column 3 were determined from the areal-weighted average of the soundings within each cell, as determined from the bathymetric chart. The average depth corresponds to the distance from the lower datum of the expansion alternative to the upper surface elevation for the appropriate disposal period. For the initial disposal period, this distance is measured from the average bottom elevation to el +4.0 ft mlw; for the subsequent disposal period, this distance is measured from el +4.0 ft mlw to the maximum surface elevation.

23. The total surface area was calculated based on the center line of the perimeter dikes at el +8.0 ft mlw. The difference between total and available surface area for each line of data in Table 2 reflects the reduction in storage capacity due to the dike volumes and the small area (approximately 5 percent (Cargill 1985)) required for the deposition of the coarse-grained fraction. An initial value, representing conditions existing before interior dike construction, was calculated over the depths from the bottom to el +4.0 ft mlw; the second estimate covered the range from el +4.0 mlw to the final surface elevation. The total storage capacity for each alternative was calculated as the product of the available surface area for each phase and the average depth for each phase. The final column in Table 2 is the average lift thickness for each alternative corresponding to each of the two disposal periods. The values represent results of semiannual disposal of 2.125 million cu yd of fine-grained dredged material with an initial void ratio of 10.5; this information in the last column is included for comparison purposes only. In simulating the filling of the various cells, actual lift thicknesses were used based upon the quantity of material to be dredged during a particular dredging operation and the surface area of the disposal cell to be used for that operation.

PART IV: MODELING TECHNIQUE

24. Management of confined dredged material disposal areas to provide maximum storage capacity is becoming more necessary as both the storage capacity of existing sites and the availability of land for creation of new sites decrease. Maximum site capacity is achieved through densification of the dredged material by removal of interstitial water. The volume reduction, and the resulting increase in site capacity, is obtained through both consolidation and desiccation of the dredged material.

25. Long-term management of dredged material containment areas has been facilitated by development of predictive techniques that allow accurate projection of the containment area surface elevation for repetitive disposal operations. Use of large strain consolidation test data in a finite strain mathematical model permits prediction of surface elevations to within the accuracy of measurement of the constituent variables. Techniques for predicting volume reduction resulting from evaporative drying have been developed and incorporated in the mathematical model Primary Consolidation and Desiccation of Dredged Fill (PCDDF). A user-friendly version of PCDDF, in the Automated Dredging and Disposal Alternatives Management System, ADDAMS (Schroeder 1988), was used in this study. This version is referred to as the CONS (consolidation) module of ADDAMS.

Theoretical Basis

Finite strain consolidation

26. Because many soft, fine-grained dredged materials may eventually undergo 50-percent strain or more, Terzaghi's conventional small strain theory is not technically applicable to analyses of dredged material containment areas. A more appropriate approach involves use of a large, or finite, strain consolidation theory. The most general and least restrictive of the many one-dimensional primary consolidation formulations is the finite strain theory developed by Gibson, England, and Hussey (1967).

27. The governing equation for finite strain consolidation theory is based on the continuity of fluid flow in a differential soil element, Darcy's law, and the effective stress principle, similar to the conventional consolidation theory. However, finite strain theory can additionally consider

vertical equilibrium of the soil mass, place no restriction on the form of the stress-strain relationship, allow for a variable coefficient of permeability, and accommodate any degree of strain. The governing equation is

$$\left(\frac{\gamma_s}{\gamma_w} - 1\right) \frac{d}{de} \left[\frac{k(e)}{1 + e}\right] \frac{\partial e}{\partial z} + \frac{\partial}{\partial z} \left[\frac{k(e)}{\gamma_w(1 + e)} \frac{d\sigma'}{de} \frac{\partial e}{\partial t} + \frac{\partial e}{\partial t}\right] = 0 \qquad (1)$$

where

γ_s = unit of weight of solids

γ_w = unit weight of water

e = void ratio

$k(e)$ = soil permeabilify as a function of void ratio

z = vertical material coordinate measured against gravity

σ' = effective stress as a function of void ratio

t = time

This approach is well suited for the prediction of consolidation in thick deposits of very soft dredged materials since it accounts for the large strains and nonlinear soil properties inherent in these materials.

Desiccation

28. The removal of water by desiccation from a normally consolidating dredged material layer will result in formation of a surface crust; this in turn will cause additional consolidation due to the surcharge created by crust formation. Since surface drying may be significant between disposal operations, it is essential to incorporate predictions of desiccation settlement in evaluations of disposal site capacity.

29. An empirical description of the desiccation process has been developed in terms of water balance in the upper portion of dredged material layers (Cargill 1985). Procedures for calculation of soil evaporation rates and depths of influence have been developed. Site-specific climatic conditions are incorporated in the analysis procedures. The predictive model developed uses void ratios instead of water contents in order to be compatible with the consolidation model.

Computer Model Description

30. Both the finite strain consolidation model and the empirical desiccation model have been programmed for computer solution (Cargill 1982,

1985). The program PCDDF incorporates an explicit finite difference mathematical approximation to describe the consolidation process. Monthly adjustments in the top boundary condition and location are made to account for the amount of desiccation that has occurred. In addition to material settlement that comes from a calculation of void ratio distribution, PCDDF also calculates the distribution of stresses and pore pressures throughout the dredged material layer. Any sequence of material deposition can be considered by the program. In order to use either the PCDDF or the CONS version of the computer program, laboratory test data must be obtained on representative sediment samples. Both the sediment compressibility and permeability characteristics are required by the computer model.

PART V: DREDGED MATERIAL PROPERTIES

31. Laboratory procedures for testing slurried sediments have been developed at the WES. These procedures can provide compressibility and permeability data for the large quantities of very soft materials dredged annually by the Corps of Engineers. These data are useful in analyzing the finite strain consolidation of dredged materials.

32. For very soft soils, use of a series of consolidation tests is necessary to obtain the void ratio-effective stress ($e - \sigma'$) and void ratio-permeability ($e - k$) relationships over the entire range of potential field conditions. Results of the individual laboratory tests are combined to form the appropriate $e - \sigma'$ and $e - k$ relationships for the soft materials. In this part, the necessary geotechnical laboratory data are mentioned, and the properties of the Hampton Roads dredged material, as obtained from the laboratory testing program, are presented.

Required Laboratory Testing

33. To predict the consolidation of dredged material by finite strain theory, several pieces of data are required which can be determined through a geotechnical laboratory testing program. The necessary data include specific gravity of the solid particles, the Atterberg limits (liquid limit and plastic limit), the void ratio-effective stress ($e - \sigma'$) relationship, and the void ratio-permeability ($e - k$) relationship. The specific gravity and the Atterberg limits can be determined by routine laboratory testing, while the $e - \sigma'$ and $e - k$ relationships must be determined from one or more of a number of laboratory consolidation tests.

34. For determining the $e - \sigma'$ and $e - k$ relationships, several consolidation test procedures are available; however, at present, there is no singularly recommended testing procedure for determining these relationships for soft dredged material (Poindexter 1987). The laboratory consolidation tests used by the Corps of Engineers for dredged material testing are the self-weight consolidation test, a large strain consolidation test, and the standard oedometer test. The laboratory testing procedures are presented by Cargill (1986) and Poindexter (1987, 1988); the applicability of the various tests is discussed by Poindexter (1987, 1988).

Determination of Dredged Material Properties

35. Representative samples of maintenance sediments from the Hampton Roads area were collected and subjected to geotechnical laboratory testing (Palermo, Shields, and Hayes 1981; Cargill 1985). Classification tests were performed on the dredged material sample. The material had a liquid limit of 143 and a plastic limit of 40, yielding a plasticity index of 103. This material had a specific gravity of 2.75. The material was classified according to the Unified Soil Classification System as a black highly plastic clay (CH).

36. Consolidation tests performed on the Craney Island dredged material included the oedometer, self weight, and large strain, controlled rate of strain tests. Results of these tests were combined to form the total $e - \sigma'$ and $e - k$ relationships for the dredged material, as shown in Figures 4 and 5, respectively. The oedometer test was used to get the $e - \sigma'$ and $e - k$ relationship for the foundation soil (see Figures 6 and 7). Values of individual data points for both the dredged material and the foundation are presented in Table 3.

37. For input to the computer program CONS, the void ratio-effective stress and void ratio-permeability relationships were described by fitted curves of the form $e = A\sigma^B + C$ and $e = Dk^E + F$, respectively, where A, B, C, D, E, and F are coefficients. The coefficients were determined statistically from laboratory data on the Craney Island dredged material. The equations used for the dredged material were

$$e = -3.0 + \left(\frac{\sigma'}{0.56 \times 10^{12}}\right)^{-0.09009} \tag{2}$$

and

$$e = -4.0 + \left(\frac{k}{0.279 \times 10^{-14}}\right)^{0.08065} \tag{3}$$

The equations used for the foundation soil were

$$e = \left(\frac{\sigma'}{1.52 \times 10^{5}}\right)^{-0.12019} \tag{4}$$

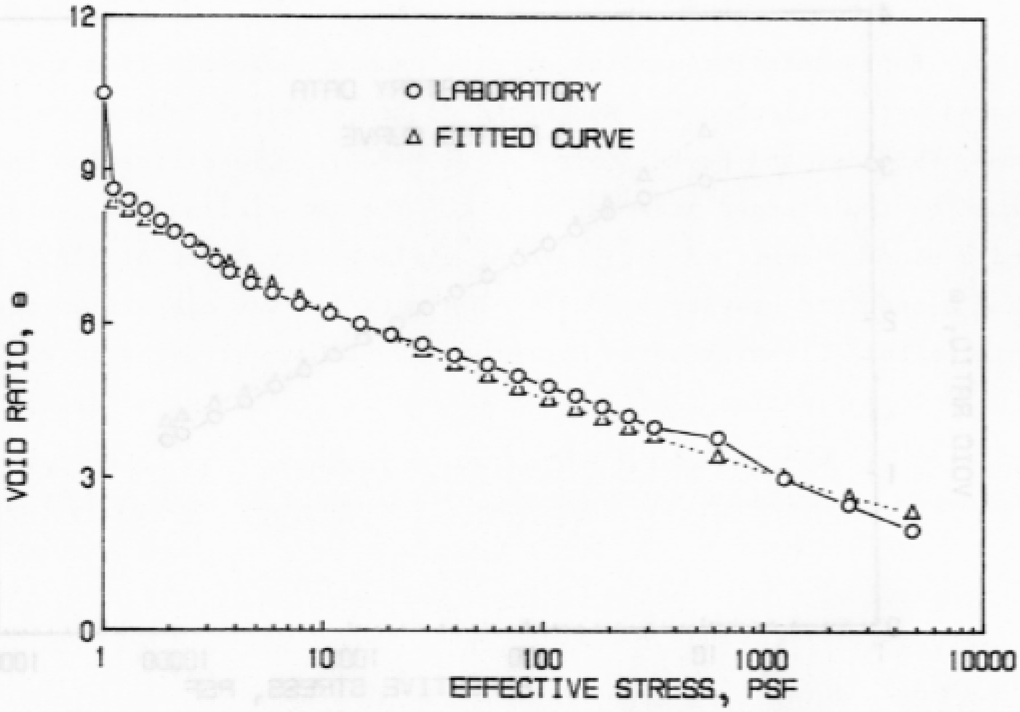

Figure 4. Void ratio-effective stress relationship for the Craney Island dredged material

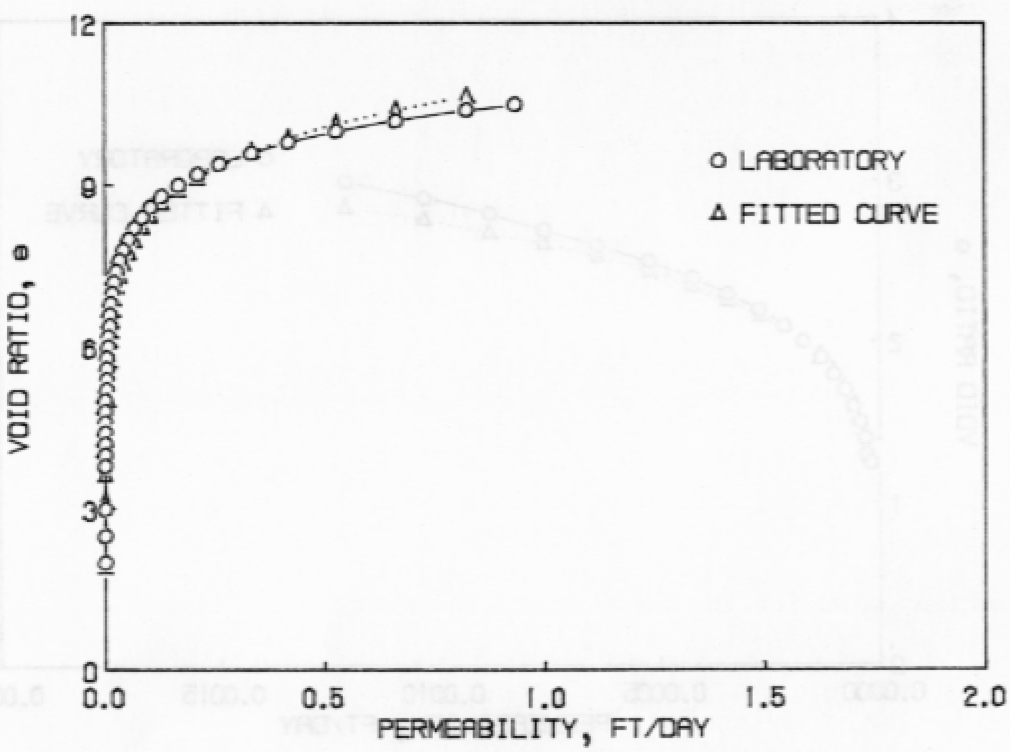

Figure 5. Void ratio-permeability relationship for the Craney Island dredged material

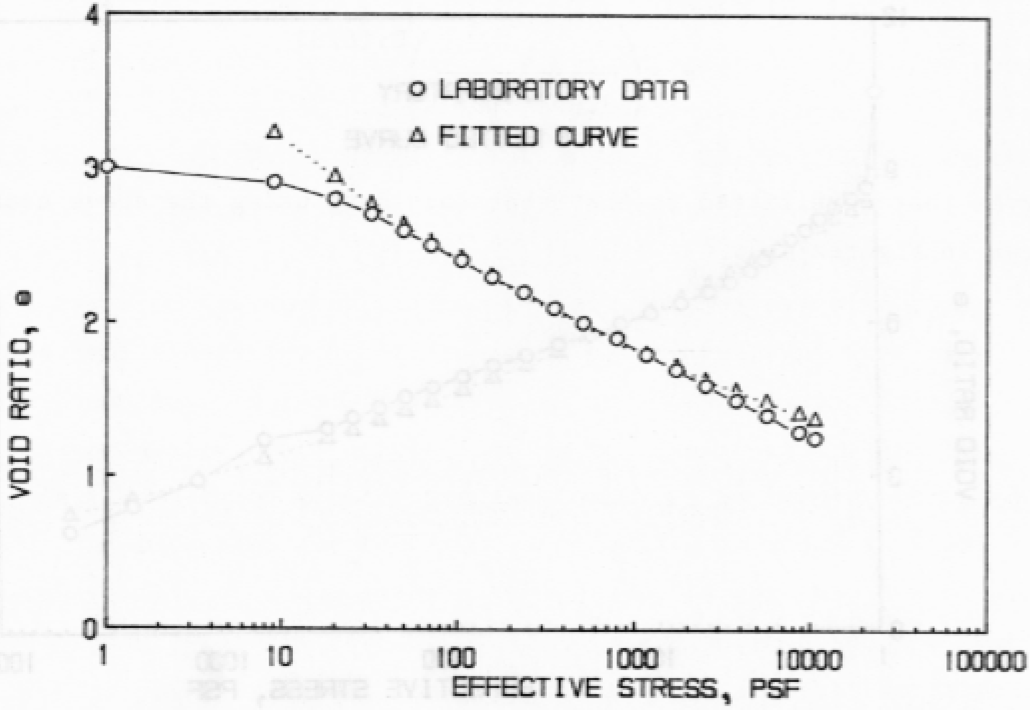

Figure 6. Void ratio-effective stress relationship for the Craney Island foundation soil

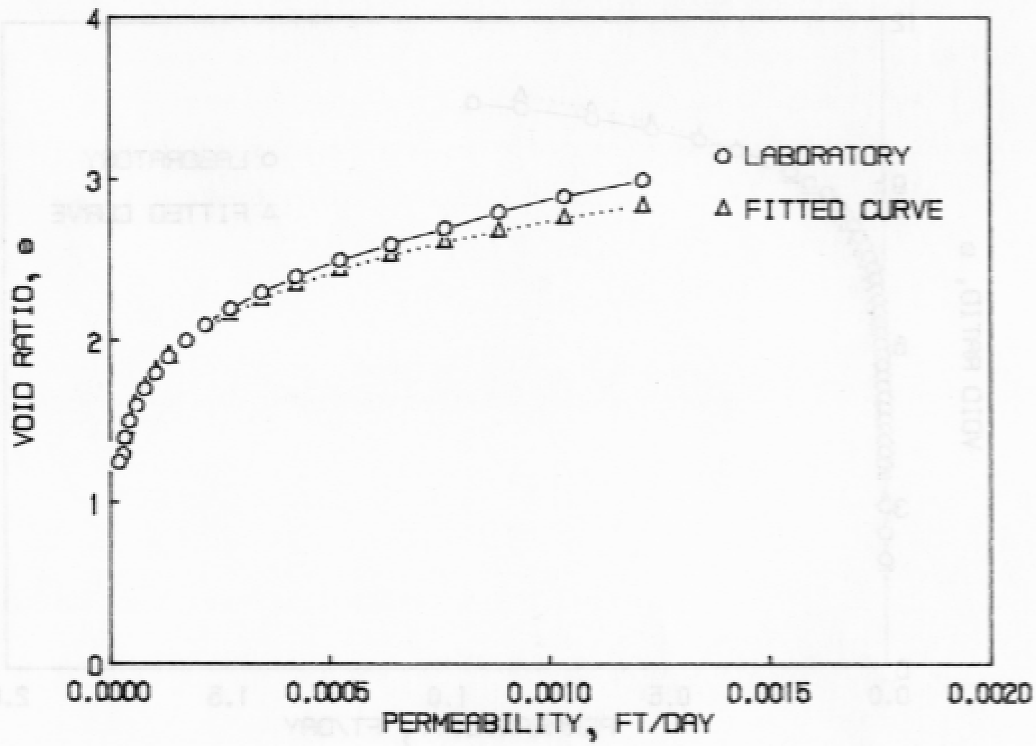

Figure 7. Void ratio-permeability relationship for the Craney Island foundation soil

and

$$e = \left(\frac{k}{3.97 \times 10^{-6}} \right)^{0.18282} \quad (5)$$

The curves that were fitted to the laboratory data using the above equations are shown in Figures 4-7.

PART VI: STORAGE CAPACITY EVALUATIONS

38. Containment areas intended for use in conjunction with recurring disposal operations must be sized for long-term storage capacity over the service life of the facility. Storage capacity is defined as the total volume available to hold additional dredged material and is equal to the total unoccupied volume minus the volume associated with ponding and freeboard requirements. The maximum available storage volume is dictated by the maximum dike height as determined by foundation conditions or other constraints and the containment surface area. Long-term storage capacity must consider not only the initial volume available for storage and the initial volume of dredged material, but also any long-term changes in the remaining storage volume available over time. The estimation of long-term storage capacity is an important consideration for long-term planning and design of new containment areas or evaluation of the remaining service life of existing sites.

39. After dredged material is placed within a confined disposal site, it immediately undergoes sedimentation, which is completed within a few days. The dredged material then enters the more time-consuming process of self-weight consolidation. Placement of the dredged material imposes a loading on the containment area foundation, which may result in consolidation of compressible foundation soils. Settlement due to consolidation of both the dredged material and foundation soils is therefore a major factor in the estimation of long-term storage capacity. Since the consolidation process is slow, especially in the case of fine-grained materials, it is likely that total settlement will not have taken place before the containment area is required for additional placement of dredged material. For this reason, the time-rate of consolidation must be considered in estimating long-term containment area storage capacity. Procedures to be used are applicable to both self-weight consolidation of dredged material and consolidation of foundation soils (Palermo, Montgomery, and Poindexter 1978; Cargill 1985; Poindexter 1987, 1988; US Army Corps of Engineers (USACE) 1987).

40. An additional factor that may affect containment area storage capacity is settlement due to desiccation of the dredged material surface. If a site is well managed to eliminate surface water, the dredged material surface will be subjected to evaporative drying and may undergo significant settlement resulting from this drying. In cases where desiccation occurs,

settlement as a function of time must be determined for dredged material subjected to the effects not only of self-weight consolidation but also of desiccation and the additional consolidation resulting from the surcharge created by formation of the desiccation crust. Procedures for prediction of dredged material settlement due to consolidation and desiccation have been developed (Cargill 1985).

41. Estimates of settlement caused by placement of subsequent lifts of dredged material should consider the continued consolidation of previously placed lifts and additional foundation consolidation. Because of the increasing complexity of calculations as additional lifts are placed, solution of all but the simplest problems is more easily accomplished through computer analysis.

42. The estimated time-settlements due to dredged material and foundation consolidation may be combined to yield a time-surface settlement relationship resulting from placement of a single lift (USACE 1986). These data are sufficient for estimation of the remaining capacity in the short term. However, if the containment area is to be used for long-term placement of subsequent lifts, a projected plot of dredged material surface height versus time (see Figure 8) should be developed (Palermo, Montgomery, and Poindexter 1978). This plot can be developed using time-settlement relationships for sequential lifts combined with surface height increases resulting from containment area filling operations. Such data may be used for preliminary estimates of the long-term service life of the containment area.

43. The saw-toothed curve shown in Figure 8 is typical of the dredged material surface elevation versus time curves obtained for containment areas that are used periodically. The time at which the containment area will fill can be determined by projecting the maximum allowable dredged material surface elevation to its intersection with the saw-toothed curve. In Figure 8, the horizontal line representing a surface elevation of 30 mlw first intersects the saw-toothed curve at approximately FY 1995, but because substantial initial consolidation will occur quickly and a minimum of 4 ft of freeboard is available between el 30 and el 34 (top of dikes), the entire FY 1995 disposal operation can be accommodated. The site is thus projected to fill during the next disposal operation (in FY 1998) when all of the dredged material cannot be contained.

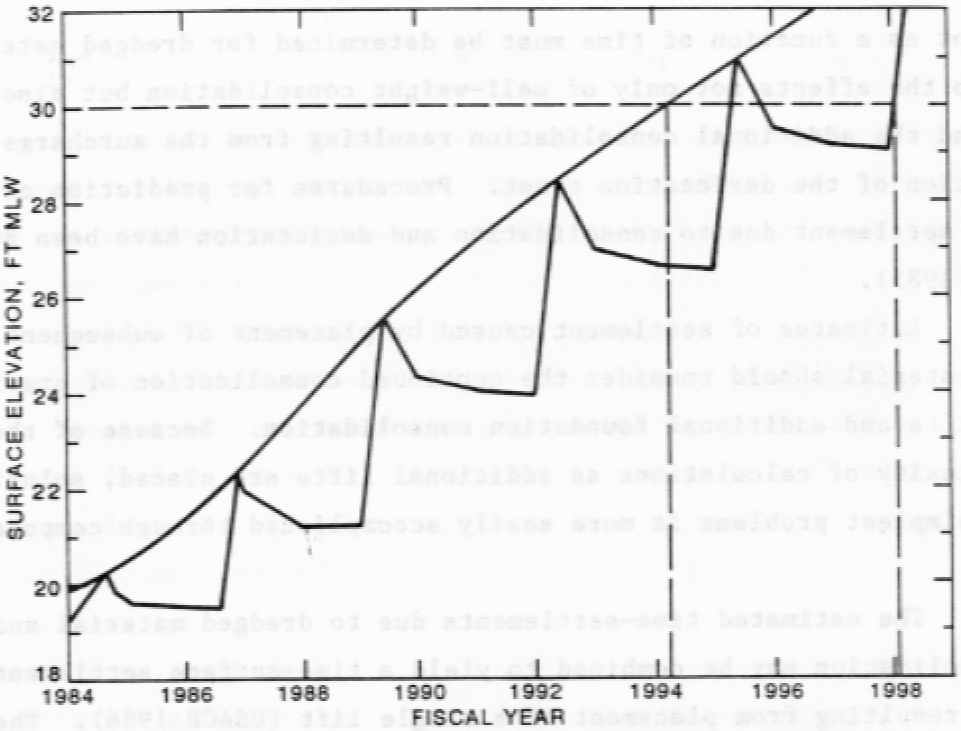

Figure 8. Comparison of typical saw-toothed curve obtained from periodic dredged material placement and smoothed curve used in this report

44. In this report, a smoothed curve will be used, instead of the saw-toothed curve, to represent the general filling trends projected for the various cells at Craney Island (see Figure 8). The smoothed curve makes it much simpler to compare numerous projections, allows the graphical data to be presented more concisely, and is much simpler for nonengineers to understand. The smoothed curve will be drawn through the peaks of the saw-toothed curves since this projection will provide a more conservative estimate of the future disposal life, i.e., a shorter disposal life. For instance, in Figure 8, the smoothed curve indicates that the site will fill during FY 1994. This projection is 4 years shorter (1994 versus 1998) than that obtained from the saw-toothed curve. In most instances, the difference in disposal life determined from smoothed and saw-toothed curves will vary by no more than approximately the length of time between disposal operations. Thus, differences between projections contained in this report and those contained in Palermo and Schaefer (in preparation) can be attributed in part to the graphical presentation method used. (Also, because the reports have very different purposes, different annual dredged material placement quantities were used in the two studies; this also directly affects the projected disposal life.)

Assumptions

45. To simulate the filling of confined dredged material containment areas, a number of assumptions must be made regarding initial site conditions, material characteristics, dredging volumes, and site operation and management. In this section, the assumptions used in the study are summarized for reference.

Initial site conditions

46. An initiation point in time was needed for the present study; this was taken as the beginning of FY 1987, with data provided by the Norfolk District. Any material present in the existing cells was considered to be soft, compressible foundation soil upon which subsequent dredged material deposits would be made. The surface elevation of each cell was determined from surveys conducted for the Norfolk District during September 1986; these elevations were then used in the filling simulations. The elevations used were as follows: north cell, el +20.0 mlw; center cell, el +15.4 mlw; and south cell, el +20.2 mlw. Furthermore, it was assumed that the interior surface of each cell was level, i.e., it was all at the stated elevation.

47. The final elevation to which dredged material could be placed was assumed to be el +30.0 mlw. This requires that all perimeter and interior dikes have a minimum final elevation of 34 mlw if 2 ft of freeboard and 2 ft of ponding depth are to be provided. Material for dike raising will come from the interior of the site; initial dike construction for the expansion site(s) is the only construction that will not use material from inside Craney Island.

Material properties

48. Over the years, the physical properties of maintenance dredged material in the Hampton Roads area have remained essentially constant. These same material properties (described in Part V) are assumed to be representative of all maintenance material to be placed in Craney Island in the future. Further, it is assumed that these properties (particularly compressibility and permeability) are also representative of the new work material that will be dredged during the various stages of the Norfolk deepening project.

49. For the purposes of this study is was assumed that the only difference in the maintenance and new work materials is the in situ void ratio at which the material exists in the channel before dredging. The in situ void ratio for the maintenance material was assumed to be 5.93 (Palermo, Shields,

and Hayes 1981; Cargill 1985) while the void ratio of the new work material was taken as 2.55 (Palermo, Shields, and Hayes 1981), based upon existing data from channel sediment samples. The quantities of material to be dredged were "bulked" from their in situ void ratios to the initial void ratio expected to exist in the containment area. An initial void ratio of 10.5 (Cargill 1985) was used for all of the hydraulically dredged materials.

Dredging and disposal quantities

50. Estimates were made by the Norfolk District regarding the quantities of new work and maintenance material to be dredged. These quantities were based upon historical data, previous hydraulic modeling studies, and best estimates of future conditions. The quantities provided by Norfolk were previously presented in Table 1.

51. The average dredged material deposit thickness was calculated for each alternative based on the available surface areas presented in Table 2. Two values for lift thickness were estimated for each configuration, consistent with the two-phase dike construction process. For the purpose of the simulations, it was assumed that the disposal volume was deposited semiannually in the entire expansion area until the dredged material surface reached approximately +4.0 ft mlw. An additional semiannual lift thickness was calculated to correspond to the construction of interior and incrementally raised perimeter dikes. For those configurations with subareas (1, 2, and 5), disposal was rotated after interior dike construction.

Site operation and management

52. It was assumed that the existing Craney Island facility will be the only available disposal site until 1993; therefore, it will receive all materials dredged in the Hampton Roads area from 1987 through 1992. This includes 4 million cu yd of maintenance dredged material plus the material from the 50-ft outbound channel deepening. (To keep terminology consistent with that used by the Norfolk District, the 4 million cu yd of maintenance material plus the 50-ft outbound deepening project are presently considered to be the "existing project.") Rotation of disposal into the three existing cells was assumed to occur in this order: the south cell in 1987, the north cell in 1988, and the center cell in 1989. This pattern of rotation was continued until one or all of the existing cells were filled or until an expansion alternative was available. For the case of Craney Island expansion, the selected expansion alternative was assumed to be available for use in 1993.

The disposal operations schedule was modified at that time to reflect sequential rotation of disposal through all cells of the particular disposal site scenario and dredging scenario of interest.

53. An active dewatering program was assumed to be planned and implemented at the Craney Island facility. The simulation of dredged material surface settlement allows flexibility in numerous input parameters describing the desiccation characteristics of a site. However, PCDDF cannot explicitly simulate specific dewatering management options, such as interior trenching. Rather, empirical coefficients are incorporated in PCDDF to provide a means to simulate the surface settlement due to desiccation of the dredged material. Thus, only one dewatering scenario was considered, as requested by the Norfolk District. This scenario assumed that maximum dewatering of the site would occur, resulting in a maximization of storage capacity. The desiccation input parameters are given in Table 4. Since the relative values of evaporation and precipitation have a major effect upon desiccation, monthly climatic data are needed in the calculations. Climatic data for Craney Island are tabulated in Table 5.

Method of Analysis

54. Evaluations were required regarding the useful life and storage capacity of Craney Island and its proposed expansion options. The useful life was determined for three disposal site scenarios. First, the disposal life of the existing Craney Island was determined without considering the expansion cell(s). Second, the disposal life of the expansion and Craney Island together was determined. Third, the disposal life of the expansion without Craney Island was determined.

55. Factored into this schedule of analysis were the six independent expansion alternatives. This resulted in 13 disposal site scenarios (one existing Craney Island, six expansions with Craney Island, six expansions without Craney Island) to be evaluated. There were also six dredging scenarios involving different aspects of the navigation channel deepening project which had to be considered for each disposal site scenario. In total, 78 evaluations were to be performed. For each evaluation, each cell of the disposal area had to be simulated and evaluated separately; the number of cells varied from one to six for the 78 evaluations. Figure 9 illustrates the

WES USEFUL LIFE STUDY
EXPANSION ALTERNATIVE #

DREDGING SCENARIOS	USEFUL LIFE IN YEARS		
	EXISTING C.I.	CRANEY ISLAND EXPANSION	
	(WITHOUT PROJECT)	WITHOUT C.I.	WITH C.I.
EXISTING PROJECT			
50 FT OUTBOUND			
55 FT OUTBOUND			
ENTIRE 55 FT			
50 FT OB+SB			
55 FT OB+SB			
ENTIRE 55 FT+SB			

Figure 9. Requested format for results of useful life evaluations (OB = outbound, SB = Southern Branch)

form in which the Norfolk District requested results of the analyses. To simplify the analysis, the format was modified to show the year in which the existing Craney Island facility will fill when used in conjunction with each expansion alternative, along with the year in which the expansion site fills both with and without considering the existing facility. One of the modified tables was completed for each of the six expansion alternatives. The year in which the existing Craney Island facility fills without use of the expansion cells is shown in a separate table.

56. The computer program CONS (the new user-friendly, personal computer version of PCDDF) was used to perform the disposal site filling simulations. Use of a computer program was required because of the numerous complicated calculations necessary to account for both consolidation and desiccation of very soft dredged materials. Because of the number and length of computer runs required in this study, the program was uploaded to the US Army Tank and Automotive Command Cray Supercomputer to facilitate the computations.

Simulation Results

57. For each dredging scenario, computer runs were made for each cell of each disposal site scenario. Results of the filling simulations for individual cells are tabulated in Appendix B. Summaries of the results are tabulated for the existing facility in Table 6 and by expansion alternative in Tables 7 through 12. It should be noted that these tables show the fiscal year in which each disposal option will fill for each dredging scenario. The actual number of years that each disposal option will be available for use can easily be calculated by either subtracting the year 1987 from the year shown for the existing Craney Island facility, or subtracting the year 1993 from the year shown for an expansion alternative, and then adding the portion of the final year during which the cell is used. For example, in Table 6, the existing Craney Island facility is projected to reach ultimate capacity in mid-FY 1997 for dredging scenario 1 (S1); the useful life of this disposal option is calculated as FY 1997 minus FY 1987 plus 0.5 year, for a useful life of 10.5 years.

Remaining Life of Existing Facility

58. If no expansion cells are constructed and the existing Craney Island facility is used to contain all material to be dredged from the Hampton Roads area (both maintenance and new work), then the site will be filled to capacity by the mid-1990s (see Table 6 and Table B1). If only the 50-ft outbound deepening project and annual maintenance dredging (dredging scenario 1) are done, the existing facility will be filled by about mid-1997 when the final existing cell (the center cell) reaches capacity. If any additional deepening is accomplished (dredging scenarios 2 through 6), the existing site will be filled to capacity in mid-1994.

59. Thus, the maximum remaining life of the existing facility is approximately 10.5 years. This remaining life will be reduced to 7.5 years if additional deepening (beyond the 50-ft outbound project) is accomplished. In summary, if the authorized deepening of Norfolk Harbor is attempted without providing an expansion of Craney Island, the existing facility will fill to capacity in 7.5 to 10.5 years, and the only portions of the deepening project

that can be contained in the facility are the 50-ft outbound and a portion of the 55-ft outbound.

60. It should be noted that all projections made in this study assume that maximum management (maximum dewatering) is accomplished at Craney Island. If intense management of the site is not accomplished each year of its remaining life, the site will fill earlier than projected in this study. Palermo and Schaefer (in preparation) found that the existing site has filled faster than projected in earlier studies partially as a result of exceptions to the management approaches presented in the Craney Island Management Plan (Palermo, Shields, and Hayes 1981) after completion of interior dike construction.

Service Life of Expansion Projects Without Craney Island

61. The existing Craney facility Island may be filled before the expansion site is completed. In this case, after completion of the selected expansion alternative, the new facility alone will then be used to contain all material dredged from the Hampton Roads area. For this analysis, it was assumed that the expansion cell will be completed and ready for use at the beginning of FY 1993. Material dredged from Hampton Roads will be placed into the new cell until the material surface reaches el +4 mlw. At this point, if the selected expansion is large enough to warrant subdivision, interior dike construction will begin and subsequent disposal operations will be rotated sequentially through the newly created subcontainments. The expansion projects considered for subdivision were alternatives 1, 2, and 5; expansion alternatives 3, 4, and 6 were not considered for subdivision but were analyzed as single cells. The results of the analyses are discussed below for each of the Craney Island expansion options.

Expansion Alternative 1

62. Completion and subsequent exclusive use of expansion alternative 1 for dredged material containment will provide adequate capacity to contain all new work and maintenance material to be dredged during the Norfolk Harbor deepening project, which is to be completed in FY 1999, plus several additional years of maintenance dredging. This expansion alternative will provide between 22.5 and 39 years of useful disposal life. A maximum of 39 years will be available if only the existing project (deepening to 50-ft outbound) is completed. If the entire deepening project is completed, then the expansion

site will be filled in mid-FY 2015, or 22.5 years after disposal is initiated into this site (see Tables 7 and B5).

Expansion Alternative 2

63. Expansion alternative 2 is considerably larger than the other proposed expansions; therefore, it has a proportionately longer useful disposal life. The projected disposal life for expansion alternative 2 ranges from 56 years for the existing 50-ft outbound deepening to 40.5 years if the entire deepening project is completed. If the latter occurs, the expansion cells will be filled during mid-FY 2033, as shown in Tables 8 and B5. This expansion alternative provides the greatest storage capacity and the longest useful life of any of the proposed alternatives.

Expansion Alternative 3

64. Expansion alternative 3 was considered to have only one cell; therefore, disposal operations could not be rotated through multiple cells. This fact, coupled with the smaller size of the expansion, will result in expansion alternative 3 filling much more quickly than the previously analyzed options. This expansion cell will be filled in mid-FY 2004 (after only 11.5 years of use) if only the existing 50-ft outbound deepening is completed. This portion of the deepening will be completed during FY 1987-88, and the remainder of the storage capacity will be consumed by maintenance material dredged between 1989 and 2004. If the existing project plus the Southern Branch deepening only (dredging scenario 4) is completed, this cell will fill by the end of FY 1999, giving a useful life of 7.5 years. If additional deepening is attempted, expansion alternative 3 will fill during deepening of the outbound channel to 55 ft; this will occur during FY 1996, only 3.5 years after the expansion cell begins receiving dredged material. Obviously, the remainder of the material from the deepening project could not be placed at the Craney Island expansion site.

Expansion Alternative 4

65. Expansion alternative 4 is slightly smaller than alternative 3 and will fill slightly sooner. Use of this expansion alternative for the existing project will result in filling of the site during mid-FY 2002 (providing 9.5 years of disposal capacity), while dredging of the existing project and the Southern Branch deepening will cause the site to fill during mid-FY 1997 (providing 4.5 years of capacity). Any of the other deepening scenarios (which include deepening of the outbound channel to 55 ft) will result in

filling of the site during mid-FY 1995, only 2.5 years after initiation of use of the site and before the deepening project is completed.

Expansion Alternative 5

66. Expansion alternative 5 was considered for subdivision into two cells, and disposal was rotated annually between the two cells. The useful life of this alternative ranges from 12.5 to 29 years. This alternative can contain all of the material from the entire deepening project. If all the project is dredged, the site will be filled during mid-FY 2005, providing a useful life of 12.5 years. If only the existing project and subsequent maintenance material are dredged, expansion alternative 5 will be able to receive material through FY 2021.

Expansion Alternative 6

67. Expansion alternative 6 is a somewhat larger version of alternative 4 and was considered to be operated as one cell. The disposal life of this alternative varied from 4.5 to 14.5 years, depending upon the dredging scenario considered. If only the existing project and maintenance material are dredged, the site will be filled in mid-FY 2007, providing 14.5 years of useful life. However, if additional portions of the deepening project are dredged, the useful life will be reduced proportionally to a minimum of 4.5 years (see Tables 12 and B5).

Service Life of Expansion Projects With Craney Island

68. The expansion cell may be completed before the existing facility is filled with dredged material, in which case disposal operations will be rotated through all cells of both the existing and new facilities. For this analysis, it was assumed that the expansion facility will be completed and ready for use in FY 1993. Dredged material will be placed into the new facility until the dredged material surface reaches el +4 mlw, at which time interior dike construction will begin if the site is large enough to warrant subdivision, and subsequent disposal operations will be rotated sequentially through all cells. As expected, when the existing facility can be used in conjunction with the expansion facility, the useful life of both facilities is increased since more time is allowed and more drying can occur between disposal operations in a particular cell.

Expansion Alternative 1

69. When expansion alternative 1 was analyzed with the existing facility, the useful life of the entire facility was predicted to extend through FY 2038 for dredging scenario 1 and through mid-2023 for dredging scenario 6, the two extremes of useful life. This represents an increase in disposal life for the Craney Island facility of approximately 6 to 10 years for the various dredging scenarios. The specific increase associated with a particular dredging scenario can be determined from Table 7; this table also lists the year in which the existing facility will be filled when used in conjunction with the expansion.

Expansion Alternative 2

70. Expansion alternative 2 was predicted to have the longest useful life of the alternatives considered. This expansion will last well into the 21st century. If all of the deepening is completed, the expanded Craney Island facility will be filled in FY 2037, 45 years after completion of the expansion facility. If only the 50-ft outbound deepening is completed, the life of the facility will be extended until approximately the end of FY 2054 with a useful life of 62 years from completion of the expansion.

Expansion Alternative 3

71. Use of the existing Craney Island with expansion alternative 3 will increase the disposal life of the entire facility by 2.5 to 7.5 years. If only the existing project (dredging scenario 1) is completed, the expansion will be available for use through FY 2011, 7.5 years longer than the expansion will last if used alone. For the portions of the deepening project which include both the 55-ft outbound and the Southern Branch (dredging scenarios 5 and 6), alternative 3 will fill in FY 1988, 6 years after completion of the expansion and before the entire deepening project is completed.

Expansion Alternative 4

72. Being the smallest of the proposed expansions, alternative 4 will fill most rapidly, even when used in conjunction with the existing facility. This cell is projected to fill within 4.5 to 15.5 years after completion of the expansion. If only the existing project is dredged, the site will fill in mid-FY 2008, while it will reach capacity in mid-FY 1997 if attempts are made to dredge the entire deepening project. There is a 2- to 8.5-year increase in expansion site life when this site is used in conjunction with the existing facility.

Expansion Alternative 5

73. Expansion alternative 5 has a useful life that ranges from 23 to 36 years. This alternative will contain the entire quantity of new work material from the channel deepening, as well as all maintenance material dredged during the deepening and for some years afterwards. If the entire project is dredged, the site will be filled by the end of FY 2015 (within 23 years of completion). If only the existing project and subsequent maintenance material are dredged, this expansion alternative will provide storage capacity through FY 2028.

Expansion Alternative 6

74. If used together with the existing site, expansion alternative 6 will contain all material from the deepening project as well as the maintenance material that must be dredged during the same time period. In this case, the site will be filled by the end of FY 2001. Other dredging scenarios in which the quantity of material to be dredged is less will have a proportionately longer useful life. The maximum life for this alternative is 20 years and occurs if only the existing project and maintenance work are dredged.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

75. Expansion of the existing Craney Island will be necessary in the very near future since the existing facility will fill in the mid-1990s. If a new facility is available for use before the existing site is filled, the quantity of material that can be placed in the various cells will be increased as a result of additional time available for dredged material drying between disposal operations.

76. The larger expansion alternatives can provide significantly longer useful life than can some of the smaller alternatives, such as alternatives 3 and 4. Expansion alternative 2 will provide disposal capacity for the longest time of any of the expansions considered in this study. Therefore, from a site capacity perspective, alternative 2 would be the expansion alternative of choice.

77. If the entire deepening project is to be completed, and all of the material dredged after completion of the expansion (in about 1993) is to be contained within the expansion cell(s), then only expansion alternatives 1, 2, and 5 can be considered for construction since they have adequate capacity to contain the necessary quantity of dredged material. Expansion alternatives 3, 4, and 6 will fill before the deepening project is completed.

78. In selecting an expansion alternative, consideration must be given not only to the disposal site capacity but also to the geotechnical, hydraulic, social, and political factors.

Recommendations

79. An expansion alternative should be selected and constructed as soon as possible. It is recommended that the expansion be completed before the existing site is filled. This will provide a disposal site in the immediate future as the existing site reaches ultimate capacity from containment of materials dredged during the Norfolk Harbor deepening project and annual channel maintenance.

80. Both the existing and new confined disposal facilities should be operated to maximize their useful life. Procedures recommended in the Craney

Island Management Plan (Palermo, Shields, and Hayes 1981) should be followed in all cells. This should include timely initiation of surface trenching following cessation of disposal operations in a particular cell.

81. Representative samples of the materials to be dredged should be taken from each portion of the deepening project, and the material properties should be determined. If these properties are significantly different from those used in this study, the projected useful life of the selected expansion alternative should be reevaluated. Representative samples should be also be taken annually of maintenance material to be dredged since the characteristics of these materials may change as the deepening project alters the sources, quantities, and deposition locations of sediments.

82. If projected quantities of material or schedules for dredging are altered significantly, reevaluation of the predicted useful life should be undertaken.

83. Monitoring within the Craney Island facility and its expansion should be accomplished no less frequently than annually. During the deepening project, it is recommended that monitoring be accomplished quarterly. The monitoring should include aerial surveys and settlement plate and piezometer data collection. Field data should be compared with the predictions in this study. If good agreement is not obtained, the reason for the discrepancy should be determined and corrected.

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Table 1

Quantities of Sediment To Be Dredged

FY	500B	550B	SB45	SB40	50IB	55IB
New Work Dredging Quantities (1,000 cu yd)						
1987	2,168					
1988	4,642					
1993		4,893				
1994		5,131				
1995		4,523				
1996			3,739			
1997			3,739	2,235		
1998					1,228	
1999						3,974
Maintenance Dredging Quantities (1,000 cu yd)						
1988	4,000					
1989	4,000					
1990	4,000					
1991	4,000					
1992	4,000					
1993	4,000					
1994	4,000					
1995		4,200				
1996		4,200				
1997			4,295			
1998				4,313		
1999					4,313	
2000						4,474

Table 2

Summary of Spatial Dimensions of the Alternative Configurations

Expansion Alternative No.	Expansion Alternative Unit	Average Bottom Elevation ft, mlw	Average Depth ft	Total Surface Area acres	Available Surface Area acres	Storage Capacity*	Average Lift Thickness ft*
1	1	-15.02	19.02	1,698.40	1,250.03	38.36	1.65
	1A	4.00	26.00	958.00	894.20	37.51	2.30
	1B	4.00	26.00	740.40	702.25	29.46	2.93
	Total					105.33	
2	2	-11.62	15.62	2,485.60	1,972.36	43.47	1.04
	2A	4.00	26.00	885.90	828.01	34.73	2.48
	2B	4.00	26.00	872.60	819.36	34.37	2.51
	2C	4.00	26.00	740.40	702.47	29.47	2.93
	Total					142.04	
3	3	-12.60	16.60	740.40	484.86	12.99	4.24
	3	4.00	26.00	740.40	694.66	29.14	2.96
	Total					42.13	
4	4	-6.80	10.80	662.60	463.71	8.08	4.44
	4	4.00	26.00	662.60	613.83	25.75	3.36
	Total					33.83	
5	5	-7.29	11.29	1,456.40	1,206.11	21.97	1.71
	5A	4.00	26.00	720.20	664.44	27.87	3.10
	5B	4.00	26.00	736.20	693.36	29.08	2.96
	Total					78.92	
6	6	-5.00	9.00	998.40	743.00	10.79	2.77
	6	4.00	26.00	998.40	937.91	39.34	2.20
	Total					50.13	

Note: The initial line of values for each alternative applies from the bottom elevation for that alternative to el +4 mlw; subsequent lines apply from el +4 mlw to el +30 mlw and are presented for each cell of the expansion alternative.

* Expressed in millions of cubic yards.

** Lift thickness refers to 6-month disposal volumes of 2.125 million cu yd at an initial void ratio of 10.5; actual lift thickness will vary for the particular dredging scenario of interest.

Table 3

Consolidation Characteristics of the Foundation and Dredged Material

Foundation			Dredged Material		
Void Ratio	Effective Stress psf	Permeability ft/day	Void Ratio	Effective Stress psf	Permeability ft/day
3.00	0.00	1.21E-03	10.50	0.00	9.36E-01
2.90	8.80	1.03E-03	10.40	0.08	8.21E-01
2.80	19.60	8.85E-04	10.20	0.15	6.62E-01
2.70	32.00	7.61E-04	10.00	0.22	5.26E-01
2.60	48.00	6.39E-04	9.80	0.30	4.18E-01
2.50	70.00	5.22E-04	9.60	0.40	3.31E-01
2.40	104.00	4.23E-04	9.40	0.50	2.59E-01
2.30	154.00	3.45E-04	9.20	0.62	2.09E-01
2.20	232.00	2.73E-04	9.00	0.76	1.66E-01
2.10	344.00	2.16E-04	8.80	0.92	1.30E-01
2.00	510.00	1.71E-04	8.60	1.10	1.05E-01
1.90	780.00	1.32E-04	8.40	1.30	8.35E-02
1.80	1160.00	1.03E-04	8.20	1.54	6.48E-02
1.70	1700.00	7.70E-05	8.00	1.80	5.18E-02
1.60	2540.00	5.80E-05	7.80	2.10	4.10E-02
1.50	3750.00	4.30E-05	7.60	2.44	3.24E-02
1.40	5540.00	3.10E-05	7.40	2.80	2.59E-02
1.30	8500.00	2.70E-05	7.20	3.20	2.02E-02
1.25	10400.00	1.90E-05	7.00	3.70	1.61E-02
			6.80	4.60	1.28E-02
			6.60	5.80	1.01E-02
			6.40	7.80	7.99E-03
			6.20	10.60	6.31E-03
			6.00	14.60	5.03E-03
			5.80	20.00	3.96E-03
			5.60	28.00	3.15E-03
			5.40	39.00	2.46E-03
			5.20	55.00	1.94E-03
			5.00	75.60	1.56E-03
			4.80	105.00	1.23E-03
			4.60	139.00	9.72E-04
			4.40	183.00	7.63E-04
			4.20	240.00	6.05E-04
			4.00	316.00	4.75E-04
			3.80	618.00	2.46E-04
			3.00	1240.00	1.11E-04
			2.50	2420.00	3.80E-05
			2.00	4740.00	1.00E-05

Table 4

Desiccation Input Parameters

Parameter	Active Dewatering
Surface drainage efficiency, percent	100
Maximum evaporation efficiency, percent	100
Saturation at end of desiccation, percent	80
Maximum crust thickness, ft	0.75
Time to desiccation after filling, days	180
Month when desiccation begins	June, December
Elevation of fixed water table, ft msl	+1.5
Void ratio at saturation limit	6.5
Void ratio at end of desiccation	3.2

Table 5

Norfolk, VA, Climatic Data, Average Monthly Values

Month	Pan Evaporation ft	Precipitation ft
January	0.00	0.28
February	0.00	0.28
March	0.00	0.29
April	0.39	0.23
May	0.57	0.28
June	0.57	0.30
July	0.67	0.48
August	0.51	0.49
September	0.34	0.35
October	0.26	0.26
November	0.00	0.25
December	0.00	0.26
Total	3.31	3.75

Table 6

WES Useful Life Study - Existing Facility

Dredging Scenario No.	Dredging Scenario Description	Year in Which Site Fills Existing Craney Island Without Project
S1	Existing project 50 ft OB	1997*
S2	55 ft OB	1994*
S3	Entire 55 ft	1994*
S4	50 ft OB+SB	1994*
S5	55 ft OB+SB	1994*
S6	Entire 55 ft+SB	1994*

Note: OB = outbound; SB = Southern Branch.

* Predicted to fill before end of listed year.

Table 7

WES Useful Life Study - Expansion Alternative 1 (See Figure 3)

Dredging Scenarios No.	Dredging Scenarios Description	Year in Which Site Fills: Craney Island (C.I.) Expansion, Without C.I.	Craney Island (C.I.) Expansion, With C.I.	Existing Craney Island With Project
S1	Existing project / 50 ft outbound	2031	2038	2015*
S2	55 ft outbound	2021	2033*	2012
S3	Entire 55 ft	2018	2028*	2011
S4	50 ft OB+SB	2026*	2032	2011*
S5	55 ft OB+SB	2017*	2025	2006*
S6	Entire 55 ft+SB	2015*	2023*	2006*

* Predicted to fill before end of listed fiscal year.

Table 8

WES Useful Life Study - Expansion Alternative 2 (See Figure 3)

Dredging Scenarios No.	Dredging Scenarios Description	Year in Which Site Fills: Craney Island (C.I.) Expansion, Without C.I.	Craney Island (C.I.) Expansion, With C.I.	Existing Craney Island With Project
S1	Existing project / 50 ft outbound	2040* (2048)	2040* (2054)	2021**
S2	55 ft outbound	2040* (2041)	2040* (2050)	2019
S3	Entire 55 ft	2039**	2040* (2045)	2017
S4	50 ft OB+SB	2040* (2043)	2040* (2048)	2017
S5	55 ft OB+SB	2035	2040* (2042)	2015**
S6	Entire 55 ft+SB	2033**	2037	2007**

* The year 2040 was the last year considered in the computer simulation. Therefore, the useful life is somewhat greater; the projected year in which the cell will fill is shown in parentheses.

** Predicted to fill before end of listed fiscal year.

Table 9

WES Useful Life Study - Expansion Alternative 3 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2004*	2011	2004*
S2	55 ft outbound	1996	2005	2001
S3	Entire 55 ft	1996	2002*	1999*
S4	50 ft OB+SB	2000*	2006	2002
S5	55 ft OB+SB	1996*	1998	1997*
S6	Entire 55 ft+SB	1996*	1998	1997*

* Predicted to fill before end of listed year.

Table 10

WES Useful Life Study - Expansion Alternative 4 (See Figure 3)

Dredging Scenarios		Year in Which Site Fills		
		Craney Island (C.I.) Expansion		Existing Craney Island
No.	Description	Without C.I.	With C.I.	With Project
S1	Existing project 50 ft outbound	2002*	2008*	2003*
S2	55 ft outbound	1995*	2003	2000
S3	Entire 55 ft	1995*	1999*	1998*
S4	50 ft OB+SB	1997*	2003	1998*
S5	55 ft OB+SB	1995*	1997*	1996*
S6	Entire 55 ft+SB	1995*	1997*	1996*

* Predicted to fill before end of listed year.

Table 11

WES Useful Life Study - Expansion Alternative 5 (See Figure 3)

Dredging Scenarios No.	Description	Year in Which Site Fills: Craney Island (C.I.) Expansion Without C.I.	With C.I.	Existing Craney Island With Project
S1	Existing project 50 ft outbound	2021	2028	2010
S2	55 ft outbound	2015	2023*	2009
S3	Entire 55 ft	2011	2019*	2003
S4	50 ft OB+SB	2017	2024*	2006
S5	55 ft OB+SB	2009	2019	2000
S6	Entire 55 ft+SB	2005	2015	2000

* Predicted to fill before end of listed fiscal year.

Table 12

WES Useful Life Study - Expansion Alternative 6 (See Figure 3)

Dredging Scenarios No.	Description	Year in Which Site Fills: Craney Island (C.I.) Expansion Without C.I.	With C.I.	Existing Craney Island With Project
S1	Existing project 50 ft outbound	2007*	2012	2004
S2	55 ft outbound	2000*	2009*	2000
S3	Entire 55 ft	1997*	2005	1998*
S4	50 ft OB+SB	2002*	2009*	2002
S5	55 ft OB+SB	1997*	2004	1996*
S6	Entire 55 ft+SB	1997*	2001	1996*

* Predicted to fill before end of listed fiscal year.

APPENDIX A: HISTORICAL DREDGING AND DISPOSAL RECORDS

CRANEY ISLAND DISPOSAL HISTORY

LOCATION & TYPE	DATES BEGIN	END	USAED	OTHER FED	COMMERICAL	YEARLY TOTAL	TOTAL DEPOSITS
PERMIT	Oct-56 -	Dec-56			982,566		
RE BASIN,NW	Jan-57 -	Aug-57	2,414,467				
RE BASIN,maint	Feb-57 -	May-57	302,243				
			2,716,710	0	982,566	3,699,276	3,699,276
NH,maint,HD	Oct-57 -	Nov-57	1,468,894				
NH,nw widen	Jul-58 -	Dec-58	4,708,210				
RE BASIN,maint	Jul-58 -	Sep-58	371,090				
			6,548,194	0	0	6,548,194	10,247,470
NH,SB,maint&nw	Jan-59 -	Apr-59	5,159,218				
NOB APPROACH	Jun-59 -	Aug-59		1,964,503			
RE BASIN,maint	Aug-59 -	Sep-59	940,351				
			6,099,569	1,964,503	0	8,064,072	18,311,542
NH,maint&nw	27-Oct-59 -	01-Jan-60	2,099,627				
CI ANCH,nw	25-Nov-59 -	22-May-60	4,643,020				
N&W PIERS A&B	10-Dec-59 -	27-Dec-59			127,630		
NAVY,DEGAUS	11-May-60 -	20-May-60		41,368			
			6,742,647	41,368	127,630	6,911,645	25,223,187
NH,SB,maint,HD	04-Oct-60 -	10-Nov-60	674,431				
RE BASIN,maint	20-May-61 -	20-Aug-61	1,042,693				
N&W PIERS,nw	02-May-61 -	30-Sep-61			687,634		
D&S PIERS,maint	01-Aug-61 -	17-Nov-61		817,673			
			1,717,124	817,673	687,634	3,222,431	28,445,618
N&W PIERS,nw	01-Oct-61 -	02-Mar-62			825,161		
S of N&W	24-Mar-62 -	02-Apr-62			119,740		
NH,maint, HD	03-Apr-62 -	25-Apr-62	1,258,530				
ESCI,barge reha	31-Aug-62 -	05-Sep-62			55,939		
CNN,maint,HD	05-Sep-62 -	22-Sep-62	766,893				
N&W PIERS,maint	14-Sep-62 -	10-Oct-62			156,645		
			2,025,423	0	1,157,485	3,182,908	31,628,526
NH,maint,HD	22-Sep-62 -	21-Oct-62	1,910,338				
NNSY	15-Oct-62 -	21-Oct-62		26,376			
RE BASIN,maint	05-Jan-63 -	01-Apr-63	795,559				
N&W PIERS	11-Feb-63 -	24-Feb-63			67,924		
NNSB	24-Feb-63 -	02-Mar-63			26,500		
NOB & D&S PIERS	02-Mar-63 -	13-Jun-63		521,419			
			2,705,897	547,795	94,424	3,348,116	34,976,642
NOB,maint	14-Jan-64	12-Mar-64		357,575			
NH,maint,HD	07-May-64	29-Jun-64	1,579,115				
RE BASIN,maint	02-Jun-64	30-Sep-64	603,878				
THIMBLE SHOALS,HD	23-Jun-64	02-Jul-64	63,920				
NOB,maint	27-Jul-64	12-Sep-64		371,275			
N&W,maint	10-Sep-64	02-Oct-64			148,853		
			2,246,913	728,850	148,853	3,124,616	38,101,258

RE BASIN,maint	01-Oct-64	05-Jan-65	603,878				
NH 40,maint,HD	03-Mar-65	02-Jun-65	2,618,550				
NNSY,maint,HD	14-May-65	22-May-65		107,900			
ESCI,BR	12-Jul-65	24-Jul-65			64,755		
NOB,maint	26-Jul-65	07-Oct-65		602,060			
HRSD,TP	03-Aug-65	31-Aug-65			1,096		
N&W,maint	11-Sep-65	12-Sep-65			4,770		
			3,222,428	709,960	70,621	4,003,009	42,104,267
N&W PIERS,maint	08-Oct-65	12-Oct-65			28,613		
NOB,D&S PIERS	10-Oct-65	07-Dec-65		466,515			
NH45maint,HD	03-Sep-65	01-Dec-65	2,333,940				
NH45,nw	23-Mar-66	30-Sep-66	2,931,330				
CI FUEL DEPOT	20-Aug-66	19-Nov-66		360,815			
			5,265,270	827,330	28,613	6,121,213	48,225,480
NH45,nw	01-Oct-66	16-Jan-67	1,465,600				
RE BASIN,maint	24-Sep-66	21-Apr-67	1,032,198				
NH45,nw	26-Oct-66	22-Dec-66	176,575				
NH40,maint,HD	29-Oct-66	19-Dec-66	1,197,650				
N&W,nw	20-Nov-66	11-Jan-67			281,960		
PMT,VPA,nw	17-Jan-67	17-Apr-67			1,004,959		
CNN45,nw	25-Mar-67	30-Sep-67	3,258,490				
NH45,nw	22-Apr-67	22-Aug-67	3,588,859				
C&O,NN,nw	27-Aug-67	22-Oct-67			420,710		
			10,719,372	0	1,707,629	12,427,001	60,652,481
CNN45,nw	01-Oct-67	11-Jan-68	1,629,245				
ATLAS CEMENT	15-Jan-68	20-Jan-68			46,590		
NP&IA	12-Jan-68	13-Feb-68			811,471		
NOB,maint	20-Feb-68	27-Apr-68		715,366			
NH45,maint,HD	26-Jan-68	08-Feb-68	236,247				
NH40,maint,HD	04-Feb-68	02-Mar-68	716,262				
NNSY,maint,HD	07-Feb-68	24-Feb-68		72,193			
NH45,maint	06-Apr-68	25-Jul-68	1,508,336				
CNN45,nw	08-Sep-68	01-Oct-68	230,630				
			4,320,720	787,559	858,061	5,966,340	66,618,821
NOB & D&S PIERS	14-Sep-68	28-Nov-68		538,103			
NH40&45,maint,HD	29-Jan-69	03-May-69	2,305,462				
CI FUEL DEPOT,nw	16-Feb-69	17-Apr-69		583,635			
CNN45,nw	13-May-69	30-Dec-69	1,898,300				
			4,203,762	1,121,738	0	'5,325,500	71,944,321
D&S PIERS,maint	06-Nov-69	13-Feb-70		225,500			
NIT,VPA	06-Nov-69	18-Nov-69			115,925		
N&W,maint	23-Oct-69	05-Nov-69			180,967		
NNSY,maint,HD	02-Jan-70	03-Feb-70		71,200			
NH40&45,maint	02-Jan-70	10-May-70	1,978,980				
CNN,maint	10-May-70	16-May-70	188,610				
NP&IA	09-Jan-70	11-Feb-70			493,425		
RE BASIN,maint	07-Mar-70	11-May-70	800,407				
N&W,maint	30-Mar-70	19-May-70			112,476		
DEGAUS RANGE	24-May-70	25-Aug-70		327,401			
NOB,PIER 12	11-Jul-70	11-Aug-70		226,775			
N&W,maint	23-Sep-70	01-Oct-70			71,672		
NAVY POL,nw	01-Aug-70	22-Sep-70		525,138			
			2,967,997	1,376,014	974,465	5,318,476	77,262,797

SPA,nw	31-Aug-70	30-Sep-71	8,039,700				
CNN,maint,HD	29-Sep-70	29-Oct-70	370,690				
NIT,VPA,maint	03-Oct-70	12-Oct-70			131,988		
NH40,maint	29-Oct-70	27-Nov-70	890,285				
NH45,maint	11-Dec-70	16-May-71	1,852,999				
EXXON PIERS	13-Mar-71	19-Mar-71			50,104		
NOB,maint	05-Apr-71	22-Jun-71		485,175			
NNA40,nw	16-Jul-71	22-Nov-71	4,828,174				
USCG,CI CR,nw	16-Aug-71	20-Nov-71		671,202			
			15,981,848	1,156,377	182,092	17,320,317	94,583,114
SPA,nw	01-Oct-71	01-Feb-72	2,679,887				
PMT,VPA,maint	16-Oct-71	14-Nov-71			322,389		
N&W,maint	20-Nov-71	09-Dec-71			166,698		
NH40&45,maint	02-Nov-71	04-Jan-72	1,489,000				
USCG,CI CR,maint	09-Feb-72	01-Aug-72		288,507			
RE BASIN,maint	25-Jun-72	19-Sep-72	892,487				
NOB & D&S PIERS	08-Aug-72	05-Sep-72		239,032			
ATLAS CEMENT	06-Sep-72	11-Sep-72			23,050		
NH45,maint	12-Sep-72	29-Oct-72	606,717				
			5,668,091	527,539	512,137	6,707,767	101,290,881
NIT,VPA,nw	27-Jan-73	03-May-73			1,264,045		
NH40,maint,HD	07-Feb-73	28-Mar-73	862,800				
CNN,maint,HD	23-Feb-73	28-Mar-73	238,060				
NNSY,maint,HD	17-Feb-73	22-Mar-73		57,950			
HRBT,VDOT,nw	27-Apr-73	05-May-73			183,406		
N&W,maint	09-May-73	23-May-73			152,170		
NNSB,maint	23-May-73	26-May-73			15,907		
C&O PIERS,maint	08-Jul-73	23-Jul-73			70,552		
NNSB,nw	07-Aug-73	30-Sep-73			324,976		
			1,100,860	57,950	2,011,056	3,169,866	104,460,747
NNSB,nw	02-Oct-73	31-Dec-73			956,776		
NOB&D&S,maint	10-Oct-73	01-Apr-74		916,855			
NH40&SB35,m,HD	13-Dec-73	29-Jan-74	852,544				
NNSY,maint,HD	19-Dec-73	29-Dec-73		54,823			
NNSB,nw	01-Jan-74	26-May-74			659,742		
NNSB,nw	01-Jan-74	26-May-74			769,928		
PMT,VPA	09-Jun-74	22-Aug-74			674,820		
NOB,maint	25-Jun-74	18-Sep-74		207,855			
D&S PIERS,maint	19-Jul-74	09-Sep-74		199,710			
			852,544	1,379,243	3,061,266	5,293,053	109,753,800
NIT,VPA,maint	08-Dec-74	24-Dec-74			199,174		
NH45,maint	29-Jan-75	16-Mar-75	1,622,300				
DEGAUS RANGE	15-Feb-75	23-Feb-75		36,825			
CARGILL GRAIN,BR	15-Feb-75	14-Mar-75			103,324		
NNSB,maint,BR	01-Mar-75	04-Mar-75			14,625		
YELLOW RIVER(LIM)	18-Mar-75	22-Mar-75			11,728		
NNSB,maint	22-Apr-75	30-May-75			263,948		
SO. BLOCK,SB	30-May-75	01-Jun-75			7,156		
US GYPSUM,SB	01-Jun-75	02-Jun-75			4,316		
NOB,maint	28-Jun-75	16-Sep-75		530,995			
RE BASIN,maint	07-Aug-75	17-Nov-75	770,254				
			2,392,554	567,820	604,271	3,564,645	113,318,445

NNSY,maint,HD	06-Oct-75	27-Oct-75		79,695			
NH40,maint,HD	03-Oct-75	30-Oct-75	476,270				
CNN,maint,HD	03-Oct-75	30-Oct-75	120,863				
NNSB,nw	10-Oct-75	14-Dec-75			433,649		
C&O COAL PIER,BR	14-Dec-75	18-Dec-75			26,532		
NH45,maint	18-Nov-75	21-Jan-76	539,132				
NOB,12,maint	08-Feb-76	13-Mar-76		386,425			
N&W,maint	07-Mar-76	06-Apr-76			102,916		
NORSHIPCO	07-Apr-76	06-Jul-76			334,220		
NOB,25,nw&m	03-Jun-76	03-Jul-76		622,180			
VDOT,W NOR.BR	29-May-76	15-Jul-76			12,924		
NH45,maint	17-Jul-76	04-Oct-76	2,455,287				
N & W,maint	25-Aug-76	24-Sep-76			384,679		
NOB,BOAT BASIN	27-Jul-76	17-Sep-76		67,200			
			3,591,552	1,155,500	1,294,920	6,041,972	119,360,417
NNSB,maint	28-Nov-76	03-Jan-77			110,307		
NNSB,WAY5&6,m	23-Nov-76	30-Nov-76			37,205		
C&O COAL PIER	14-Feb-77	20-Feb-77			20,045		
VDOT,JRB	14-Feb-77	20-Feb-77			6,071		
NNSY,maint,BR	08-Feb-77	23-Feb-77		39,645			
NOB,20,maint	12-Feb-77	04-May-77		528,325			
NNSB,nw,BR	26-Apr-77	17-Jun-77			333,900		
SPA,maint	05-May-77	20-Jun-77	743,476				
VDOT,JRB	06-May-77	21-May-77			5,528		
WILLOUGHBY BAY	18-May-77	20-May-77	2,400				
DEGAUS RANGE	21-May-77	21-Jun-77		130,480			
DEEP CR,NN,m,BR	25-Jun-77	15-Jul-77	42,862				
			788,738	698,450	513,056	2,000,244	121,360,661
NORSHIPCO	01-Oct-77	25-Jan-78			222,230		
NNSB,W EXT,nw	17-Dec-77	31-Dec-77			53,646		
NOB,2&4,maint	30-Jan-78	21-Feb-78		211,245			
RE BASIN,maint	21-Feb-78	05-Jan-79	1,231,637				
NH40&SB35,m,HD	02-Mar-78	29-Mar-78	303,786				
NIT,VPA,nw	15-Mar-78	13-Aug-78			954,180		
CNN,maint,HD	16-Mar-78	01-Apr-78	129,160				
CNG,nw,BR	21-Mar-78	14-May-78			108,389		
NOB,12,maint	04-Apr-78	01-Jun-78		345,990			
NOB,12,nw	04-Apr-78	01-Jun-78		146,090			
FUEL LINE TRENCH	12-May-78	11-Jun-78		8,458			
C & O PIER14,BR	24-May-78	10-Jun-78			59,400		
NIT,VPA,maint	03-Jun-78	07-Jul-78			457,370		
NH45,maint	06-Jun-78	01-Nov-78	2,147,368				
ERT,maint,BR	12-Jun-78	15-Jun-78			2,250		
PMT,VPA,nw	15-Jun-78	17-Nov-78			601,176		
			3,811,951	711,783	2,458,641	6,982,375	128,343,036
EXXON PIER	15-Oct-78	24-Oct-78			76,091		
NOB,PIER24,nw	12-Dec-78	14-Feb-79		475,435			
NOB,D&S PIERS	06-Jan-79	20-Mar-79		337,630			
YORKTOWN NWS,HD	02-Jan-79	06-Mar-79		400,971			
NIT,VPA,maint	15-Jul-79	29-Jul-79			111,255		
			0	1,214,036	187,346	1,401,382	129,744,418

VDOT,JRB,nw	16-Oct-79	24-Oct-79			9,068		
DEEP CR,NN,maint	25-Oct-79	18-Jan-80	296,375				
SPA,maint	15-Aug-79	18-Nov-79	1,477,626				
NH45,maint	10-Nov-79	18-Jun-80	2,016,563				
NOB,PIERS,m	21-Nov-79	22-Feb-80		204,007			
NNA,maint	12-Apr-80	29-May-80	1,087,166				
NOB,3-7,22,25m	21-Apr-80	18-Jun-80		407,375			
CONT GRAIN,nw&m	17-Jun-80	06-Aug-80			159,350		
N&W,nw&m	07-Jul-80	02-Aug-80			230,354		
NOB,12,maint	12-Aug-80	03-Sep-80		251,738			
RE BASIN,maint	20-Feb-80	14-Oct-80	1,637,381				
NOB,7,maint	04-Sep-80	06-Sep-80		25,092			
NIT,VPA,maint	19-Feb-80	22-Feb-80			14,823		
			6,515,111	888,212	413,595	7,816,918	137,561,336
NOB,AFDL,maint	12-May-81	05-Jul-81		247,155			
NOB PIERS,maint	23-Jul-81	14-Nov-81		651,882			
CI FUEL DEPOT,m	14-Sep-81	14-Oct-81		35,997			
			0	935,034	0	935,034	138,496,370
NH45,maint	14-Sep-81	22-Jan-82	2,228,076				
N&W,maint	19-Nov-81	01-Dec-81			96,024		
RE BASIN,maint	09-Jan-82	30-Sep-82	1,414,988				
CNN maint	24-Apr-82	23-Jun-82	648,722				
DOMINION TER,nw	25-Jul-82	30-Sep-82			330,000		
NOB,maint	22-Jan-82	19-Mar-82		891,629			
			4,291,786	891,629	426,024	5,609,439	144,105,809
RE BASIN,maint	01-Oct-82	08-Jun-83	1,414,988				
DOMINION TER,nw	01-Oct-82	09-Jun-83			989,925		
NH45,maint	14-Nov-82	24-May-83	2,183,692				
NOB PIERS,maint	28-Sep-82	11-Apr-83		366,479			
NOB,ADFL,maint	03-May-83	24-May-83		114,005			
NIT,VPA,maint	12-Jun-83	05-Jul-83			392,148		
			3,598,680	480,484	1,382,073	5,461,237	149,567,046
NOB PIERS,maint	19-Oct-83	26-Nov-83 N*		363,098			
RE BASIN.maint	01-Apr-84	30-Sep-84 S	869,433				
NH45,maint	06-Apr-84	30-Sep-84 N	1,752,340				
NOB PIER 11,m	22-May-84	06-Jul-84 N		469,639			
SPA,maint	04-Feb-84	29-Sep-84 N	2,451,377				
			5,073,150	832,737	0	5,905,887	155,472,933
RE BASIN,maint	01-Oct-84	16-May-85 S	1,391,094				
NH45,maint	01-Oct-84	14-Dec-84 N	876,171				
NOB PIERS,maint	16-Sep-84	28-Nov-84 N		775,448			
N & W,maint	23-Oct-84	24-Nov-84 N			121,457		
NIT,maint&nw	03-Feb-85	02-Apr-85 C			600,095		
NNA,maint,HD	02-Feb-85	07-Mar-85 N	183,546				
NOB PIERS,maint	07-Mar-85	01-May-85 N		610,386			
EXXON PIER,maint	16-May-85	22-May-85 N			77,150		
LEHIGH CEMENT,m	22-May-85	24-May-85 N			45,400		
NNA,maint	31-Jul-85	11-Aug-85 N	251,987				
			2,702,798	1,385,834	844,102	4,932,734	160,405,667

* Large existing site was subdivided in 1983 into three compartments:
N = north cell, S = south cell, and C = center cell.

VDOT,I-664,nw	07-Jan-86	19-Mar-86 C			997,142		
WB ELIZ R,maint	02-Feb-86	22-Mar-86 C	150,431				
NIT,nw	22-May-86	22-Jun-86 C			1,618,841		
NOB PIERS,maint	01-Jun-86	29-Jun-86 C		185,365			
NH40,maint	15-Jul-86	14-Aug-86 C	192,055				
NH45,maint	15-Jul-86	30-Aug-86 C	529,325				
			871,811	185,365	2,615,983	3,673,159	164,078,826
NOB PIERS,nw	09-Jun-87	01-Aug-87S		978,250			
NOB PIERS,nw	20-Jul-87	08-Aug-87S		153,474			
RE BASIN,maint	08-May-87	23-Aug-87S,C	1,681,024				
			1,681,024	1,131,724	0	2,812,748	166,891,574
			120,424,524	23,122,507	23,344,543		166,891,574

APPENDIX B: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - TABULATED RESULTS

Table B1

Existing Craney Island Without Expansion Projects:

Fiscal Year in Which Existing Cells Will Fill

Dredging Scenario	South	Cell Center	North
S1	1993	1997*	1991*
S2	1993*	1994*	1991*
S3	1993*	1994*	1991*
S4	1993*	1994*	1991*
S5	1993*	1994*	1991*
S6	1993*	1994*	1991*

* Predicted to fill before end of listed fiscal year.

Table B2

Existing Craney Island With Expansion Projects:

Fiscal Year in Which South Cell Will Fill

Dredging Scenario	Expansion Alternative 1	2	3	4	5	6
S1	2005	2008	1997	1996	2000	1997
S2	2003*	2007*	1995*	1994*	2000*	1994*
S3	2002*	2005*	1995*	1994*	1996*	1994*
S4	2005*	2009*	1998*	1994*	2000*	1998*
S5	1997*	2003*	1995*	1994*	1996*	1994*
S6	1997*	1998	1995*	1994*	1996*	1994*

* Predicted to fill before end of listed fiscal year.

Table B3

Existing Craney Island With Expansion Projects:

Fiscal Year in Which Center Cell Will Fill

Dredging Scenario	Expansion Alternative 1	2	3	4	5	6
S1	2015*	2021*	2004*	2003*	2010	2004*
S2	2012	2019	2001	2000	2009	2000
S3	2011	2017	1999*	1998	2003	1998*
S4	2011*	2017	2002	1998*	2006	2002*
S5	2006*	2015*	1997*	1996*	2000	1996*
S6	2006*	2007*	1997*	1996*	2000	1996*

* Predicted to fill before end of listed fiscal year.

Table B4

Existing Craney Island With Expansion Projects:

Fiscal Year in Which North Cell Will Fill

Dredging Scenario	Expansion Alternative 1	2	3	4	5	6
S1	1991*	1991*	1991*	1991*	1991*	1991*
S2	1991*	1991*	1991*	1991*	1991*	1991*
S3	1991*	1991*	1991*	1991*	1991*	1991*
S4	1991*	1991*	1991*	1991*	1991*	1991*
S5	1991*	1991*	1991*	1991*	1991*	1991*
S6	1991*	1991*	1991*	1991*	1991*	1991*

* Predicted to fill before end of listed fiscal year.

Table B5

Expansion Projects Without Craney Island:

Fiscal Year in Which Expansion Cells Will Fill

Dredging Scenario	Expansion Alternatives 1 A	1 B	2 A	2 B	2 C	3	4	5 A	5 B	6
S1	2031	2026*	2040** (2047)	2040** (2048)	2040** (2043)	2004*	2002*	2020*	2021	2007*
S2	2021	2017*	2040*	2040** (2041*)	2037*	1996	1995*	2012	2015	2000*
S3	2018	2015*	2038*	2039*	2037*	1996	1995*	2009	2011	1997
S4	2026*	2022*	2040** (2042*)	2040** (2043*)	2040*	2000*	1997*	2015*	2017	2002*
S5	2017*	2016*	2034*	2035*	2031*	1996*	1995*	2006	2009	1997*
S6	2013	2015*	2033*	2030	2028*	1996*	1995*	2005*	2005	1997*

* Predicted to fill before end of listed fiscal year.

** Fiscal Year 2040 was the last year for which disposal operations were simulated. Thus, the cell is predicted to fill sometime after the end of FY 2040; the projected year of filling is shown below in parentheses.

Table B6

Expansion Projects With Craney Island:

Fiscal Year in Which Expansion Cells Will Fill

Dredging Scenario	Expansion Alternatives 1 A	1 B	2 A	2 B	2 C	3	4	5 A	5 B	6
S1	2038	2033	2040** (2053)	2040** (2054)	2040** (2050)	2011	2008*	2025*	2028	2012
S2	2033*	2028	2040** (2050)	2040** (2047)	2040** (2043)	2005	2003	2020*	2023*	2009*
S3	2028*	2023	2040** (2044)	2040** (2045)	2040** (2043)	2002	1999*	2016	2019*	2005
S4	2032	2027	2040** (2047)	2040** (2048)	2040** (2045*)	2006	2003	2021	2024*	2009*
S5	2025	2020	2040** (2041)	2040** (2042)	2040** (2038)	1998	1997*	2016	2019	2004
S6	2023*	2016*	2036	2037	2035	1998	1997*	2014	2015	2001

* Predicted to fill before end of listed fiscal year.

** Fiscal Year 2040 was the last year for which disposal operations were simulated. Thus, the cell is predicted to fill sometime after the end of FY 2040; the projected year of filling is shown below in parentheses.

APPENDIX C: SIMULATED FILLING HISTORIES FOR INDIVIDUAL DISPOSAL CELLS - GRAPHICAL PRESENTATION

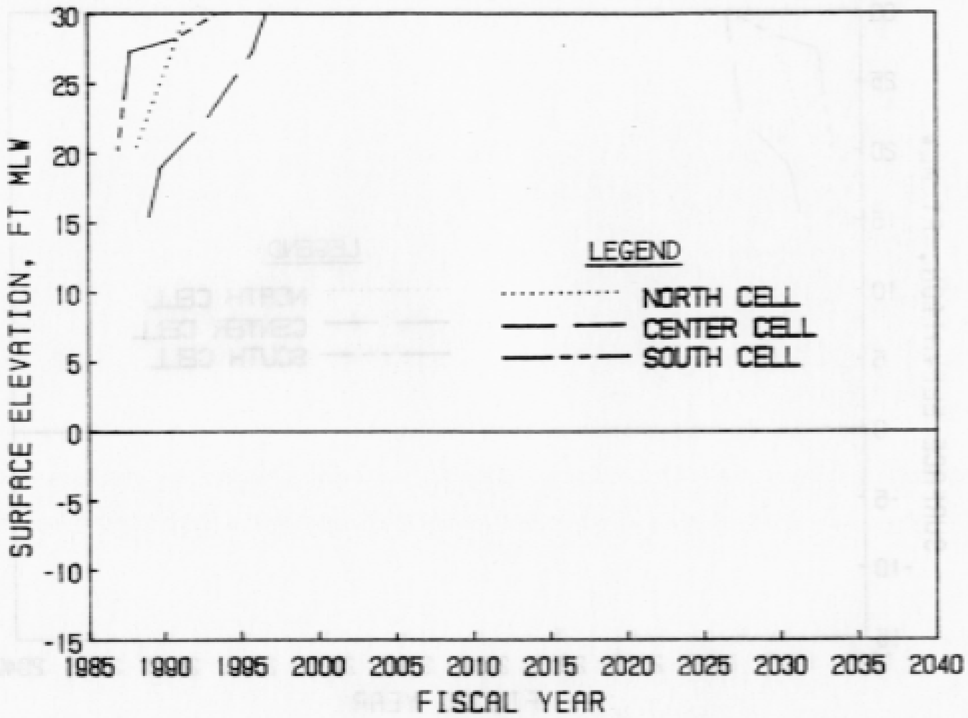

Figure C1. Existing Craney Island, Dredging Scenario 1

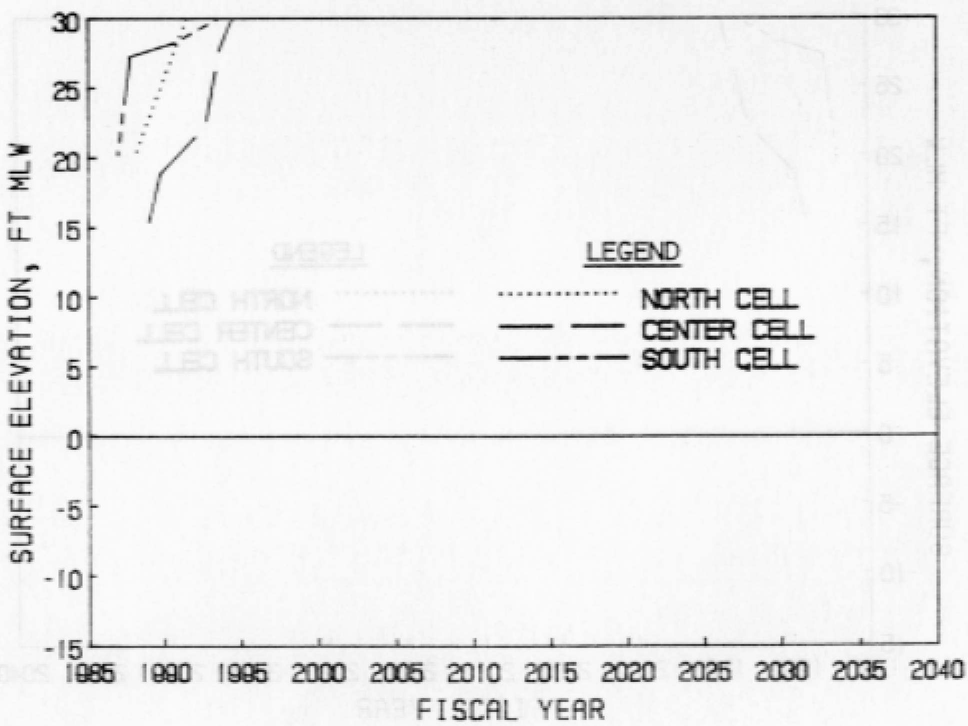

Figure C2. Existing Craney Island, Dredging Scenario 2

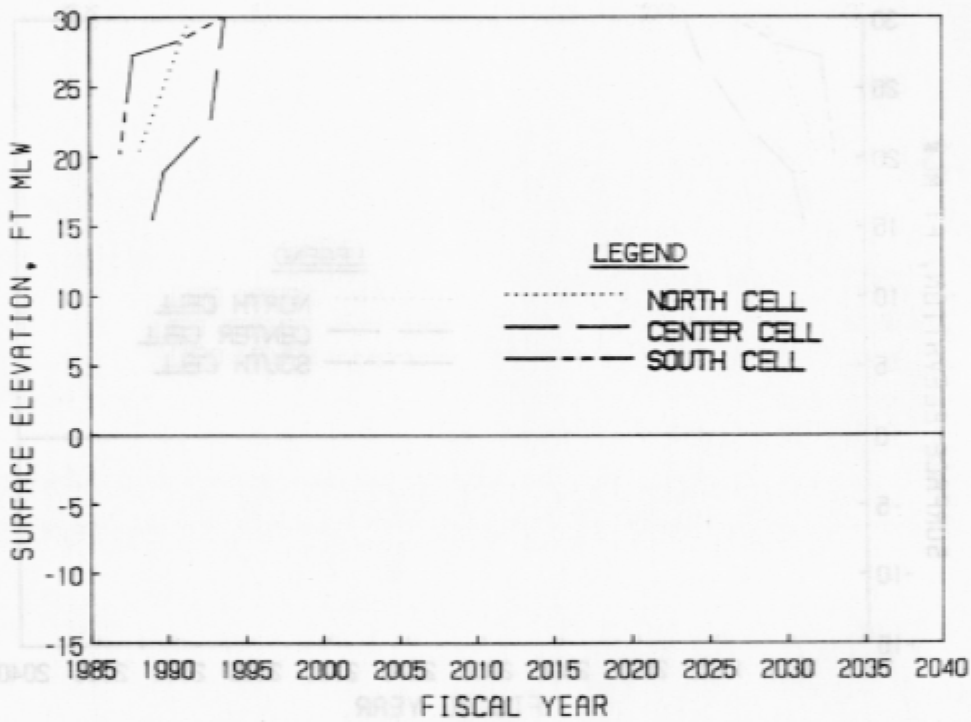

Figure C3. Existing Craney Island, Dredging Scenario 3

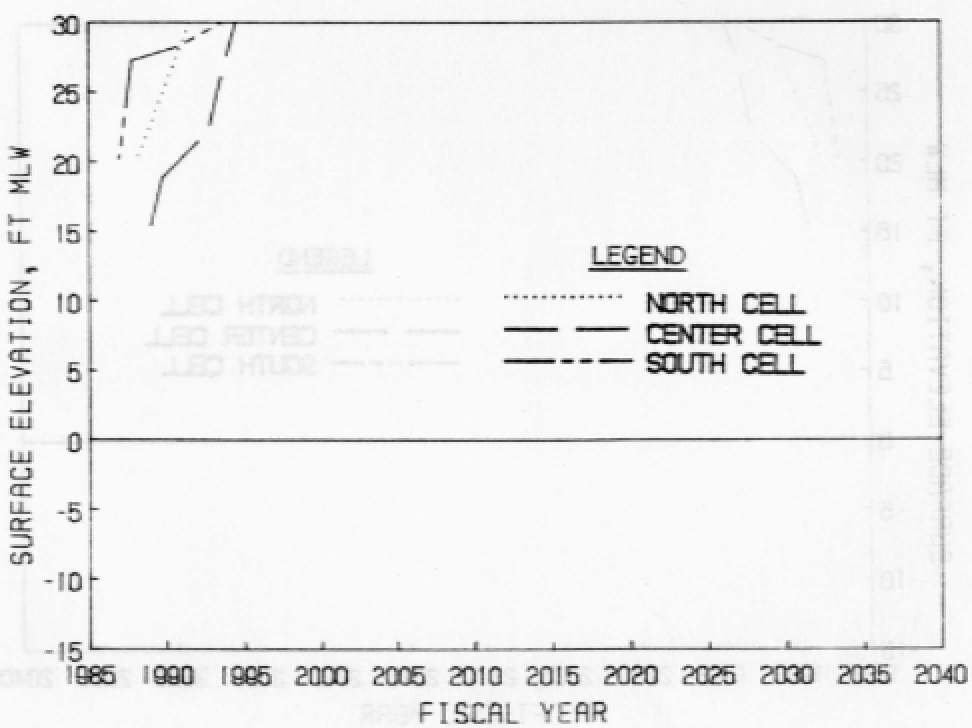

Figure C4. Existing Craney Island, Dredging Scenario 4

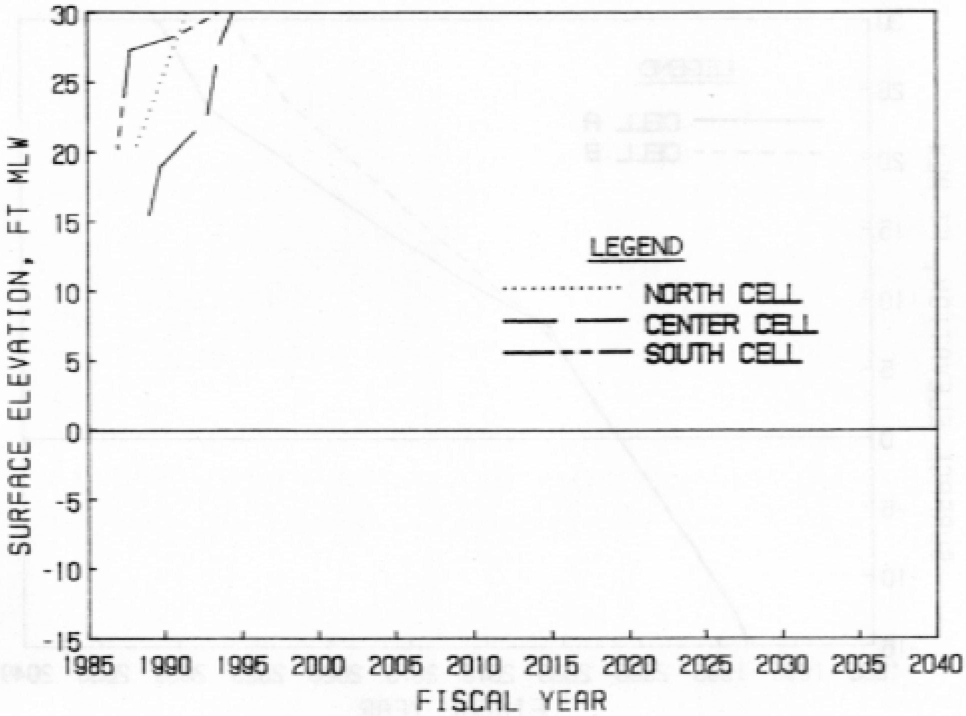

Figure C5. Existing Craney Island, Dredging Scenario 5

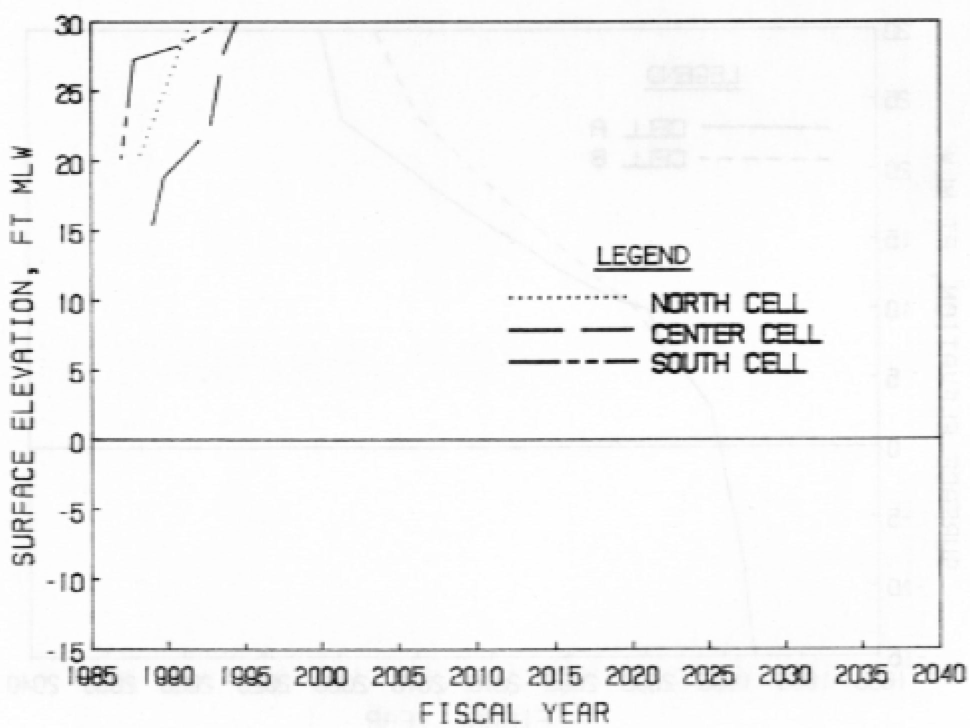

Figure C6. Existing Craney Island, Dredging Scenario 6

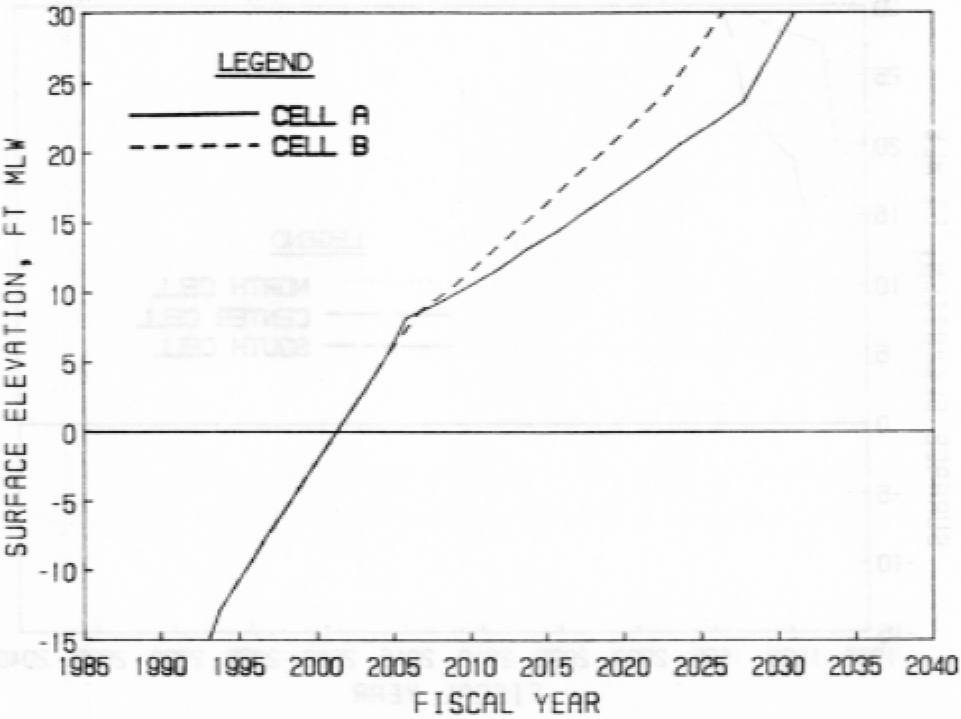

Figure C7. Expansion Alternative 1, Dredging Scenario 1

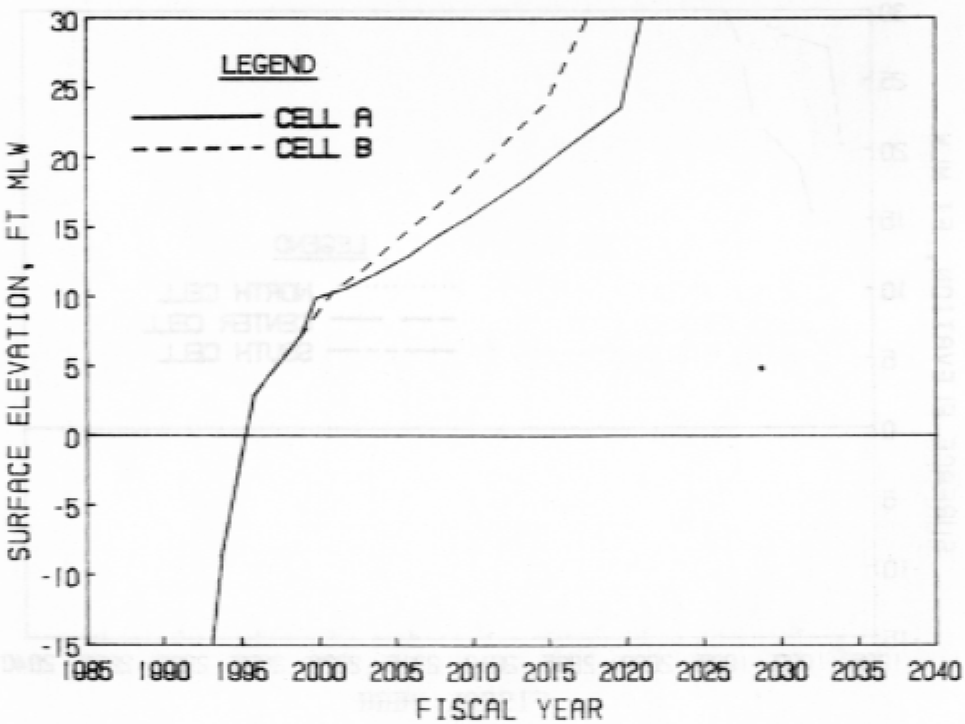

Figure C8. Expansion Alternative 1, Dredging Scenario 2

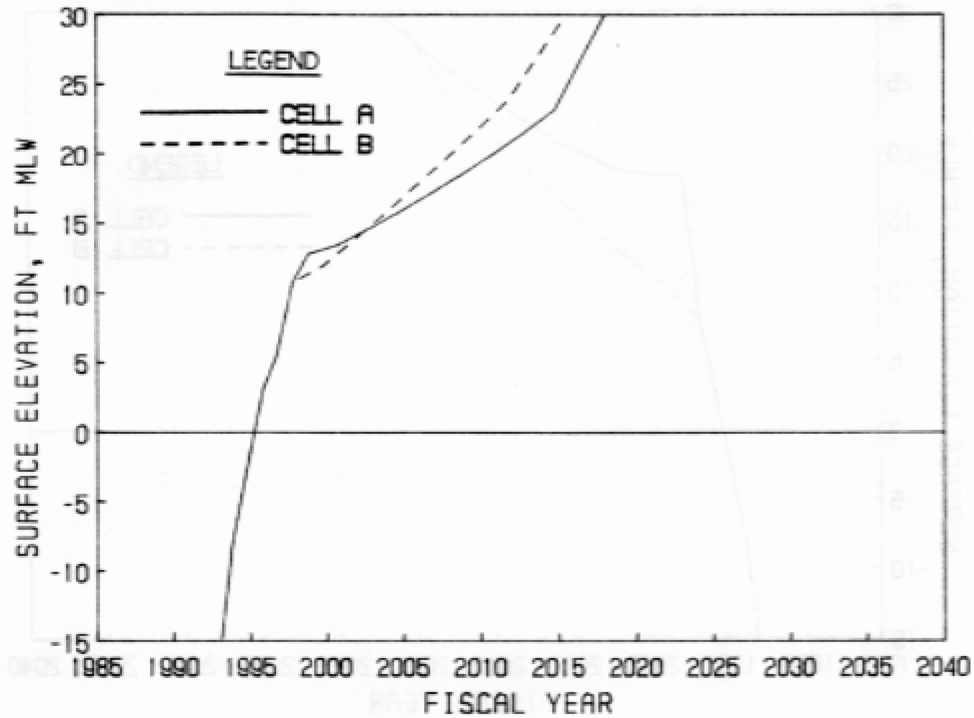

Figure C9. Expansion Alternative 1, Dredging Scenario 3

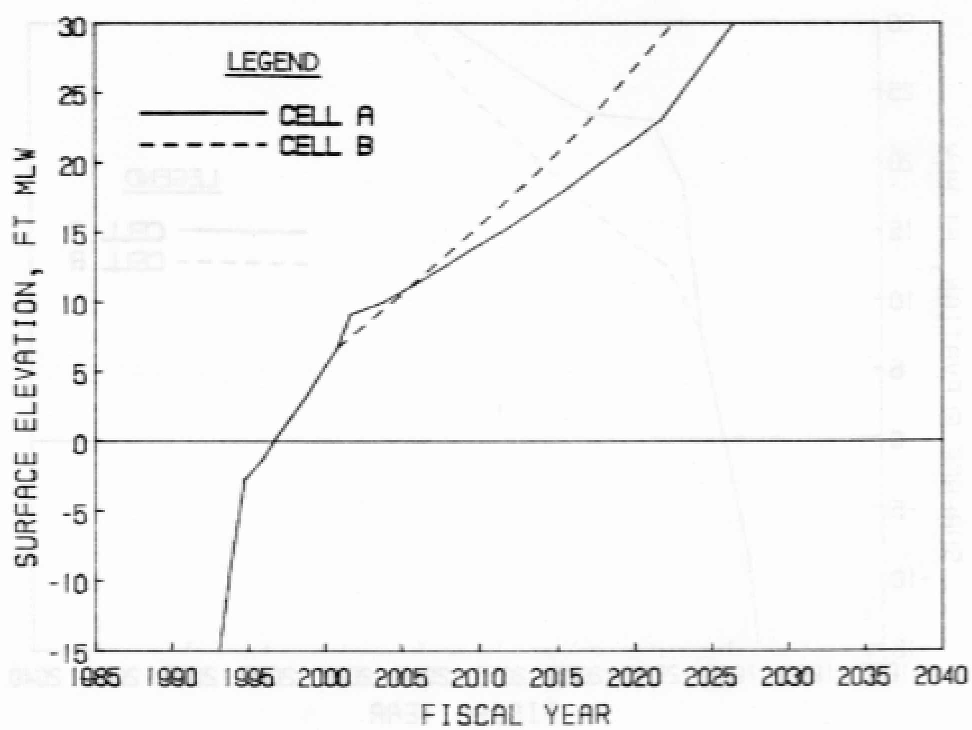

Figure C10. Expansion Alternative 1, Dredging Scenario 4

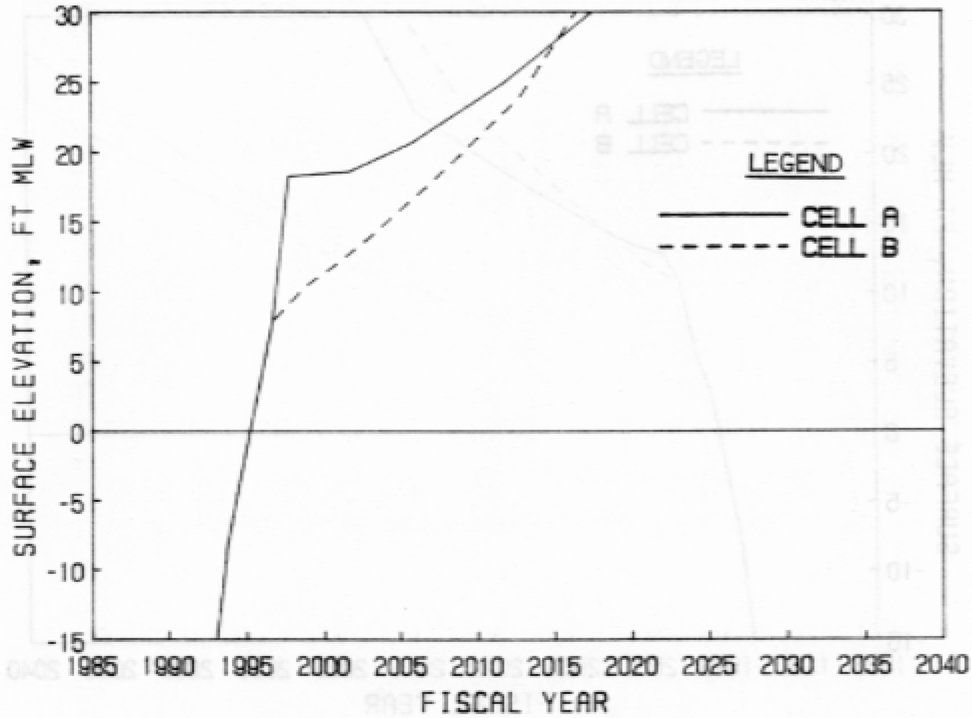

Figure C11. Expansion Alternative 1, Dredging Scenario 5

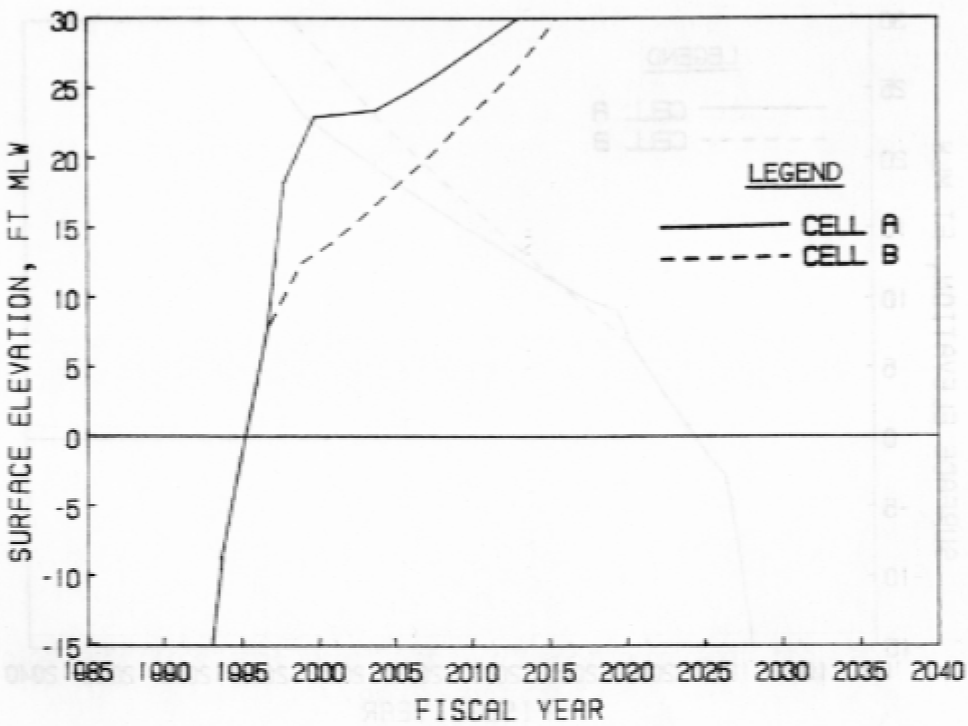

Figure C12. Expansion Alternative 1, Dredging Scenario 6

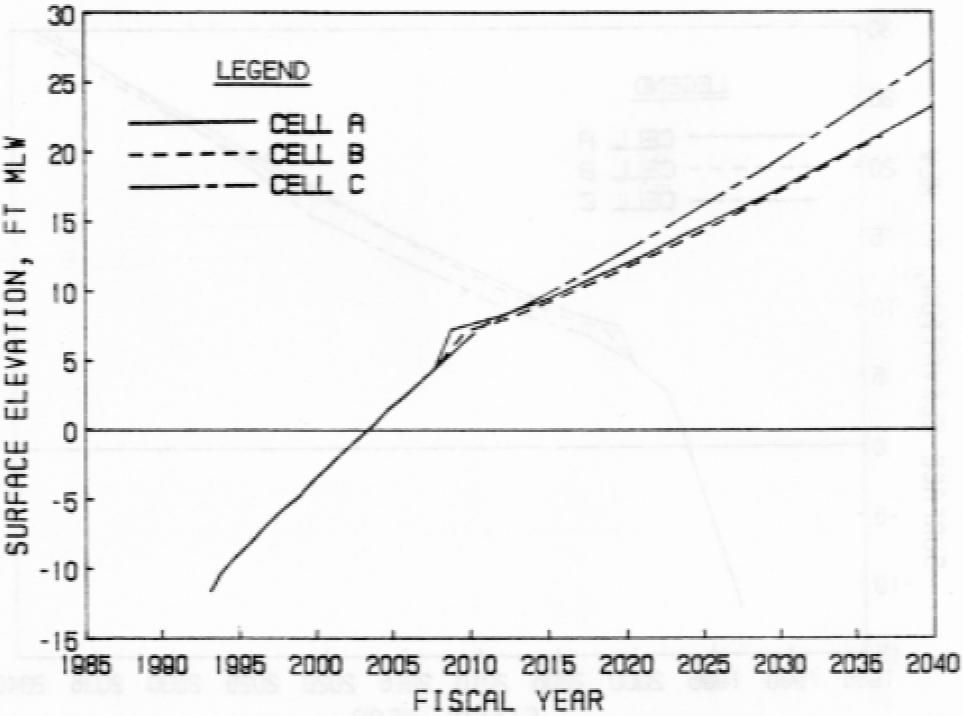

Figure C13. Expansion Alternative 2, Dredging Scenario 1

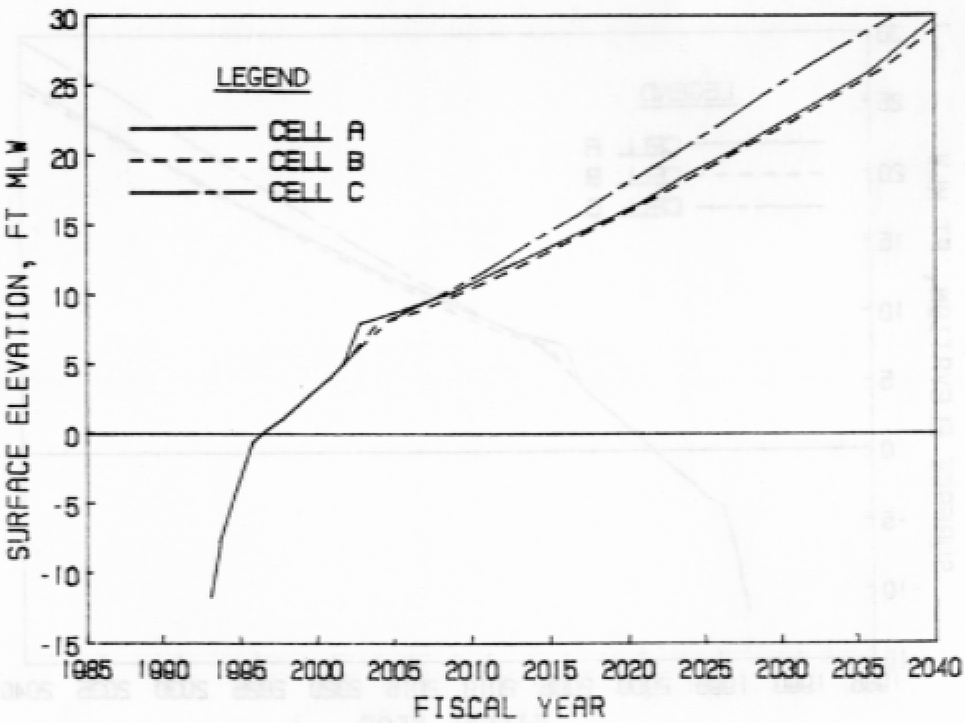

Figure C14. Expansion Alternative 2, Dredging Scenario 2

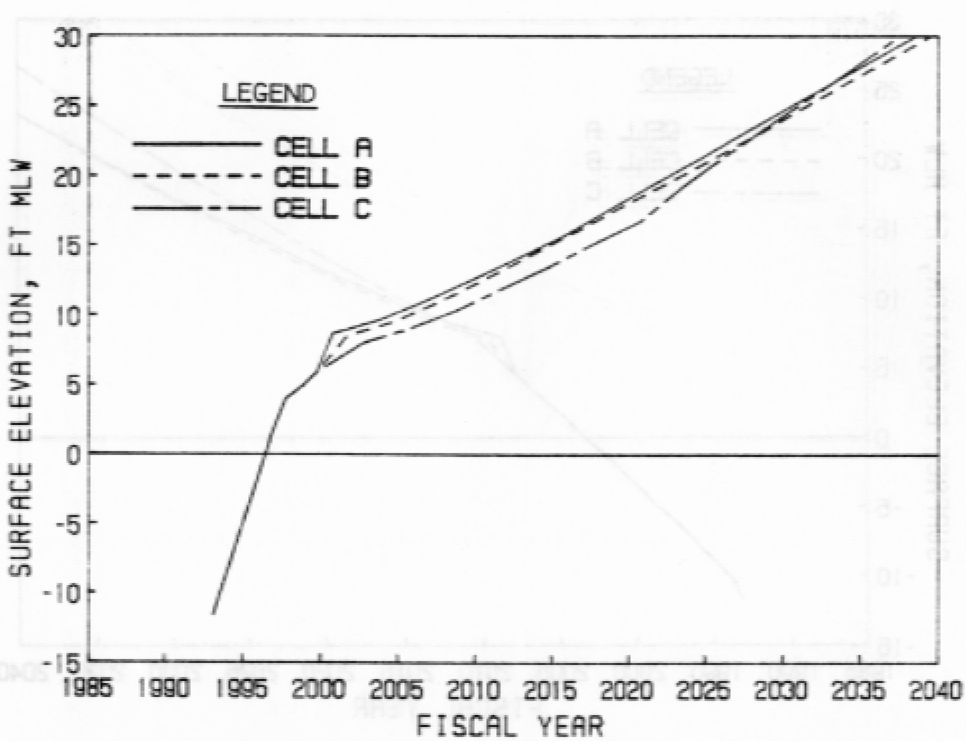

Figure C15. Expansion Alternative 2, Dredging Scenario 3

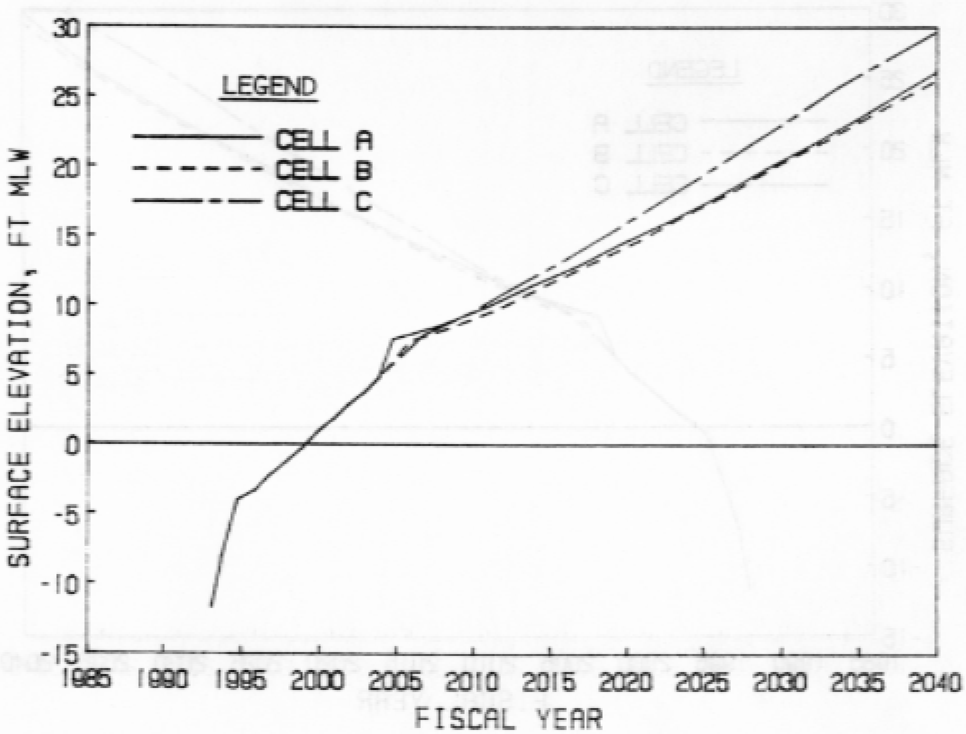

Figure C16. Expansion Alternative 2, Dredging Scenario 4

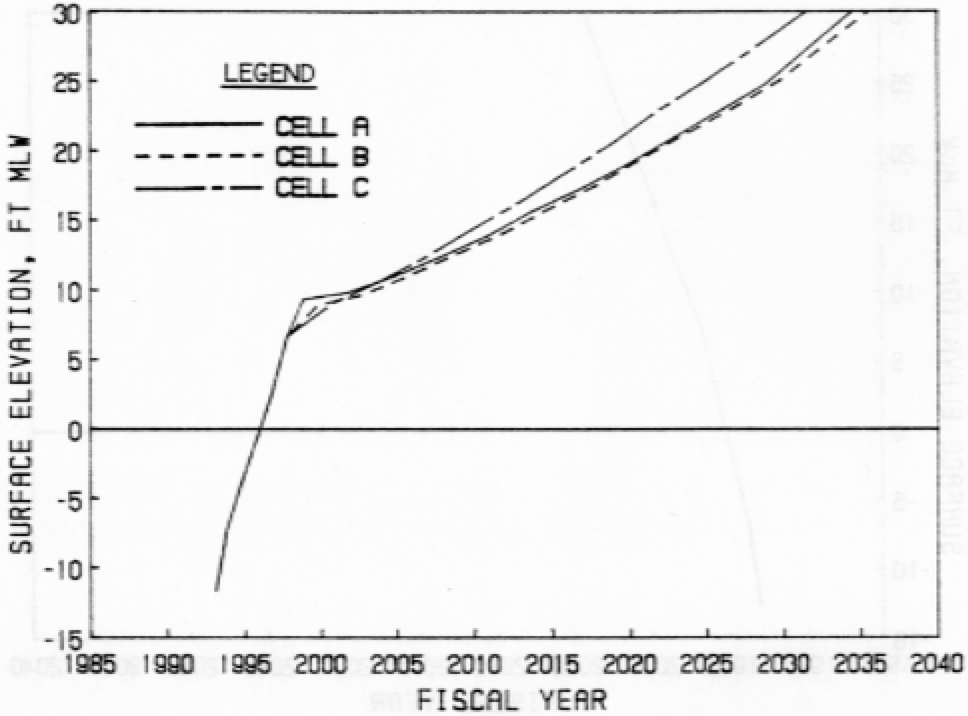

Figure C17. Expansion Alternative 2, Dredging Scenario 5

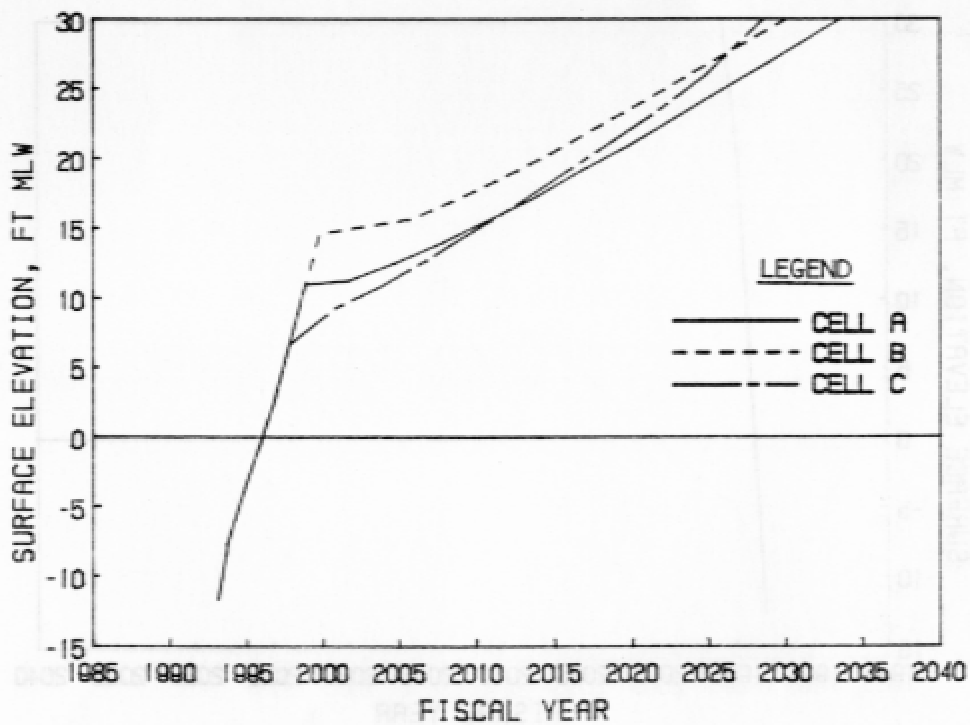

Figure C18. Expansion Alternative 2, Dredging Scenario 6

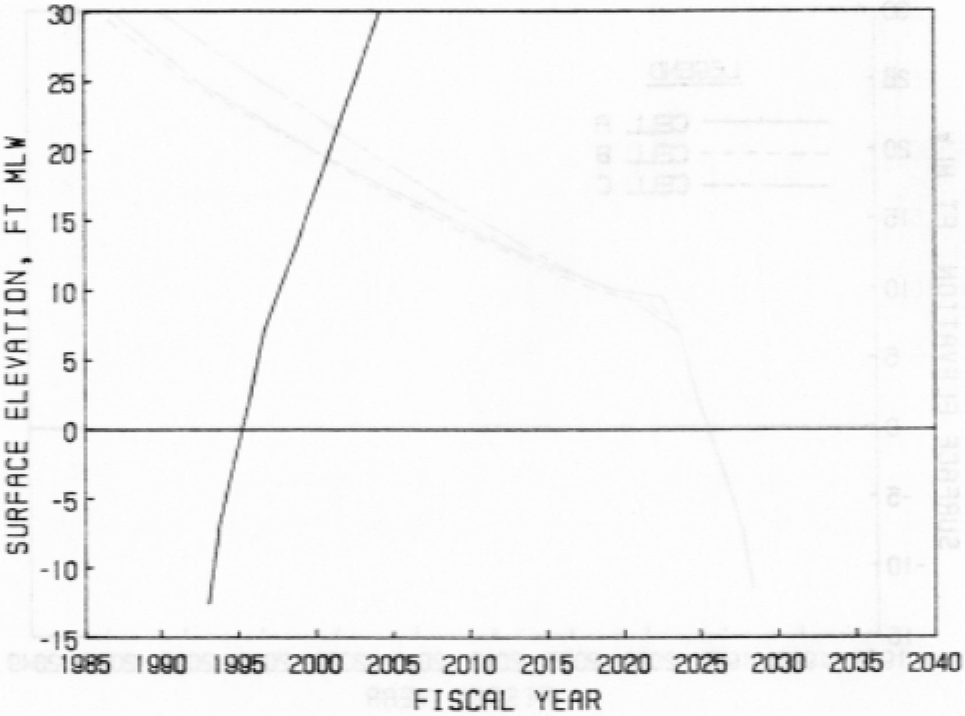

Figure C19. Expansion Alternative 3, Dredging Scenario 1

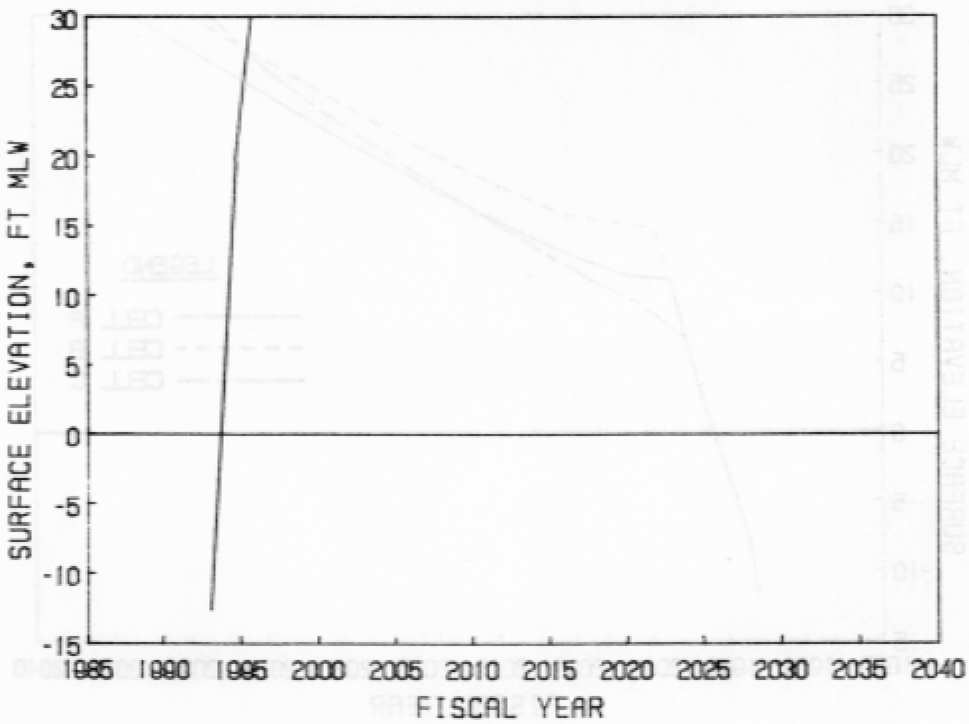

Figure C20. Expansion Alternative 3, Dredging Scenario 2

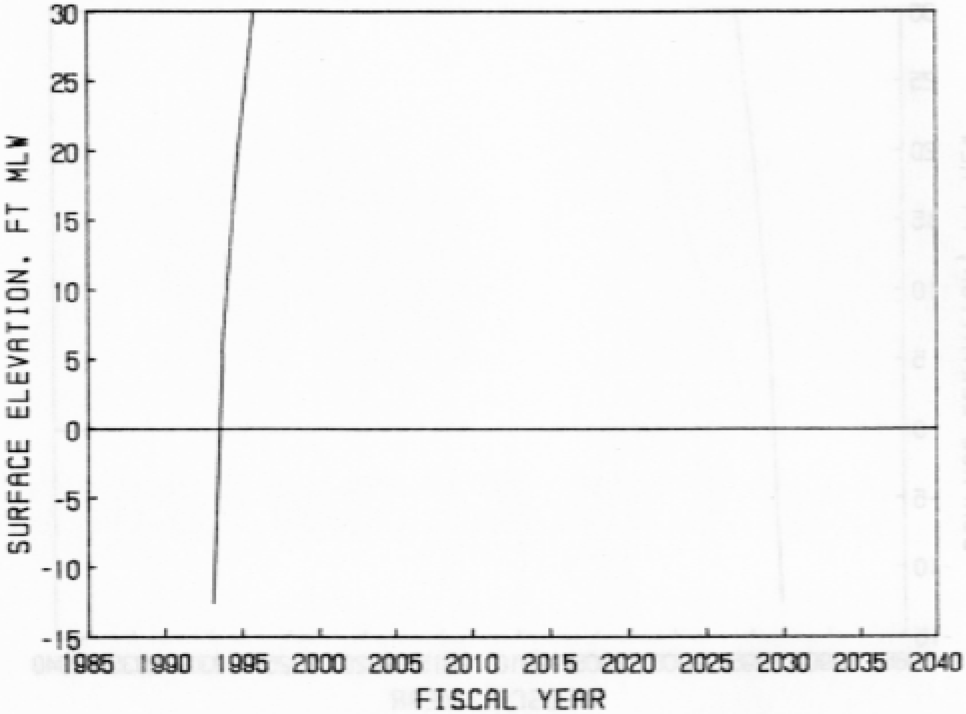

Figure C21. Expansion Alternative 3, Dredging Scenario 3

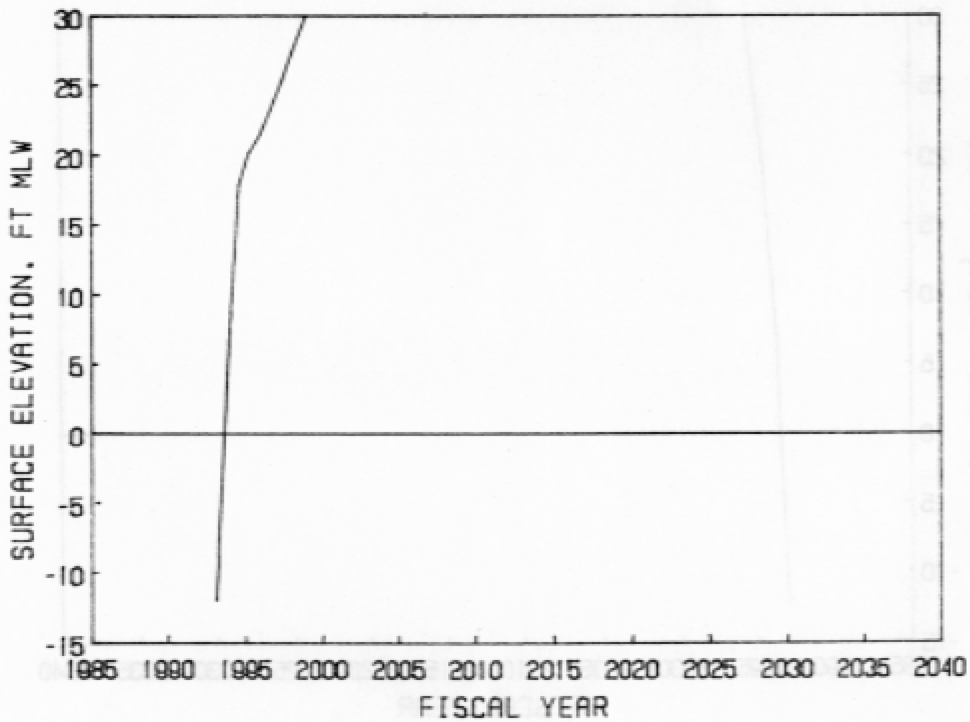

Figure C22. Expansion Alternative 3, Dredging Scenario 4

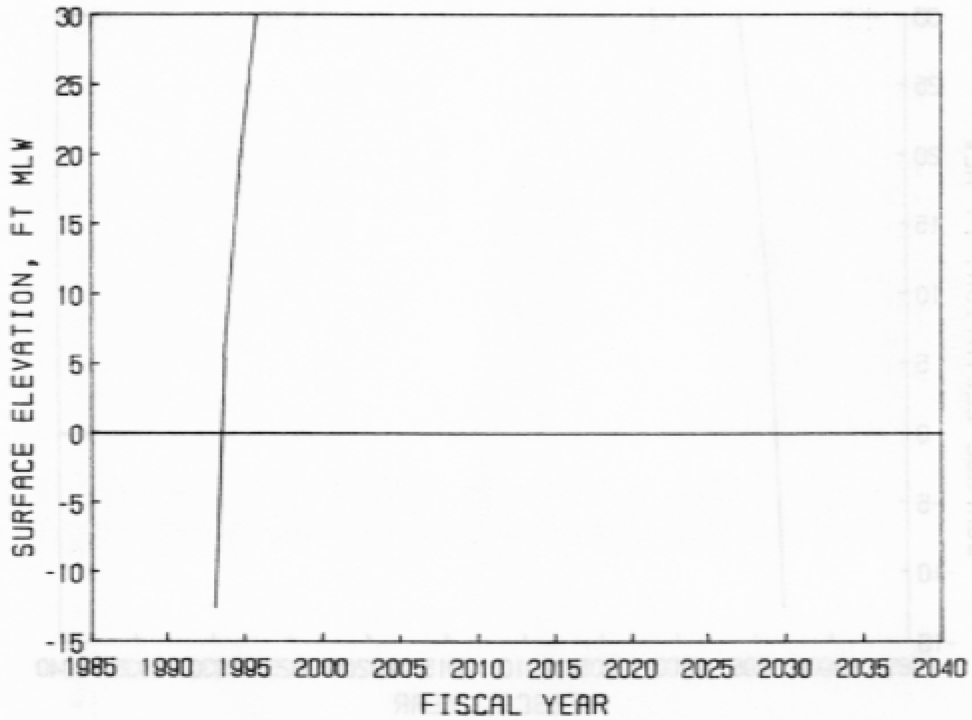

Figure C23. Expansion Alternative 3, Dredging Scenario 5

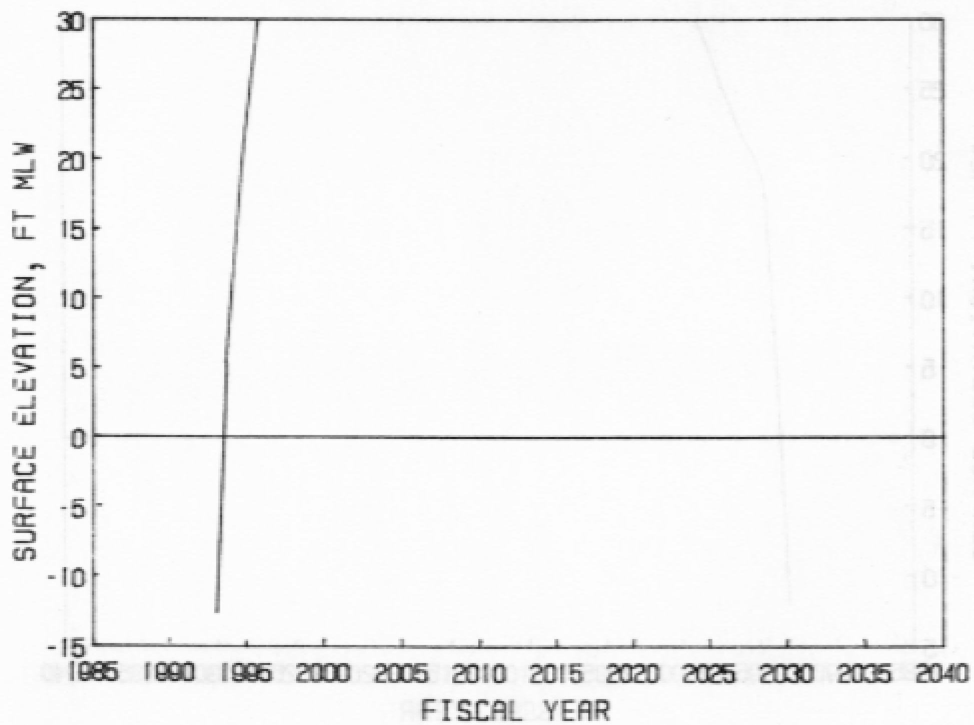

Figure C24. Expansion Alternative 3, Dredging Scenario 6

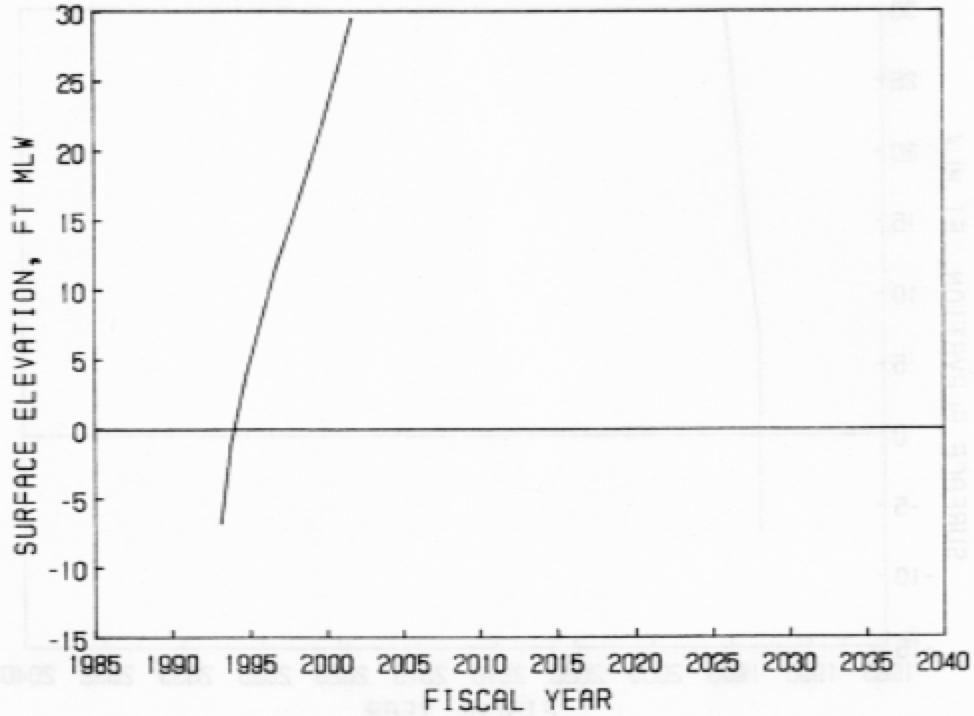

Figure C25. Expansion Alternative 4, Dredging Scenario 1

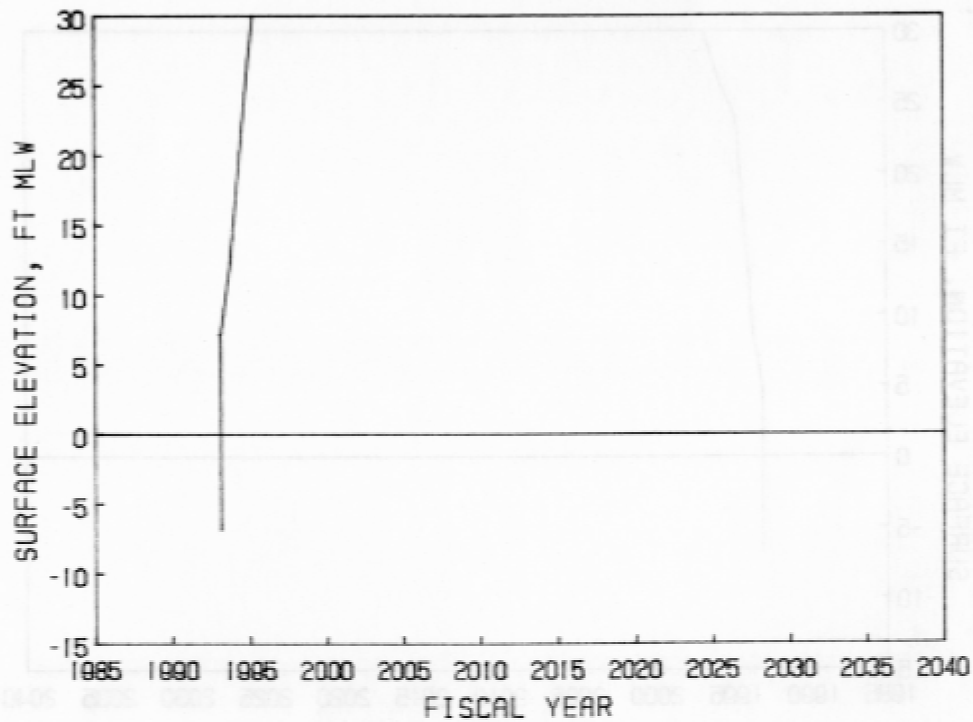

Figure C26. Expansion Alternative 4, Dredging Scenario 2

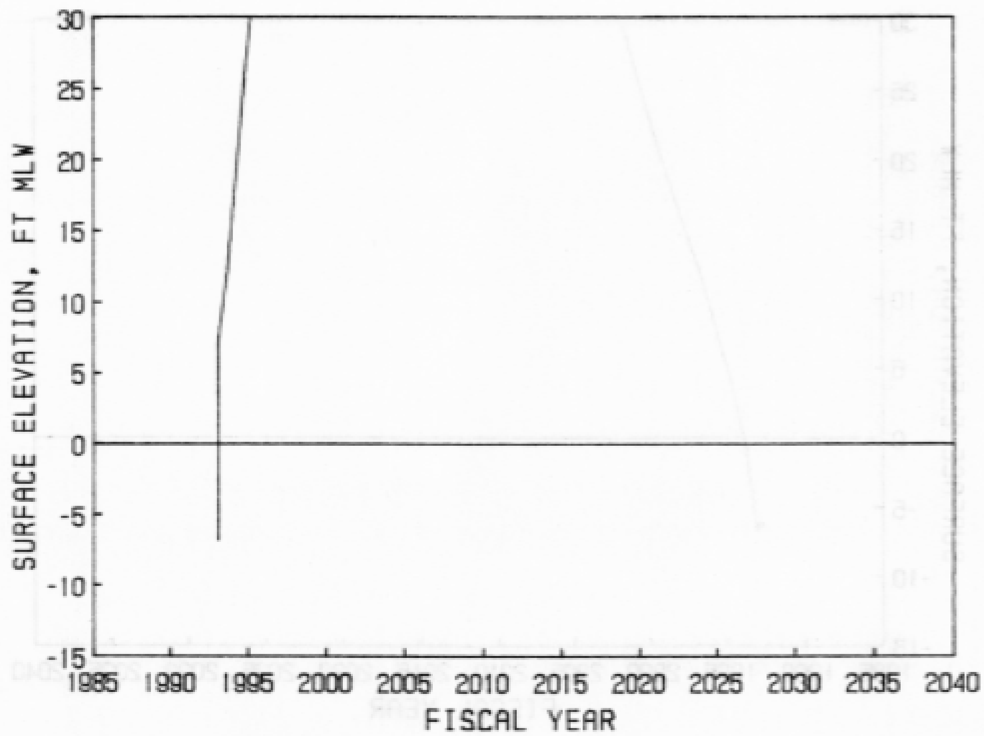

Figure C27. Expansion Alternative 4, Dredging Scenario 3

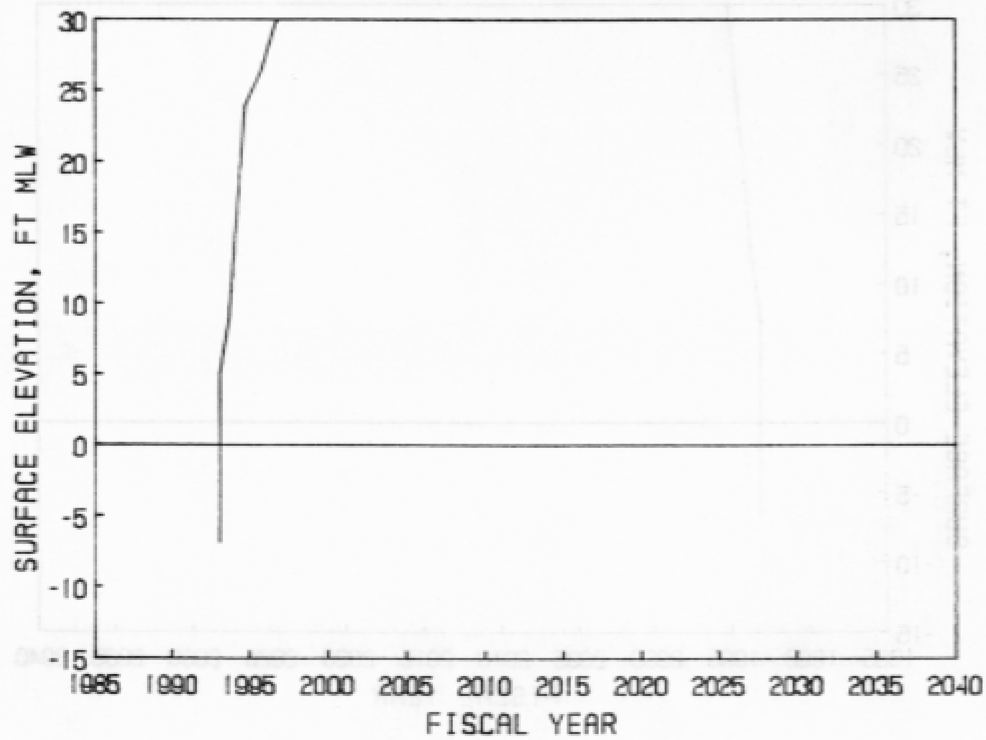

Figure C28. Expansion Alternative 4, Dredging Scenario 4

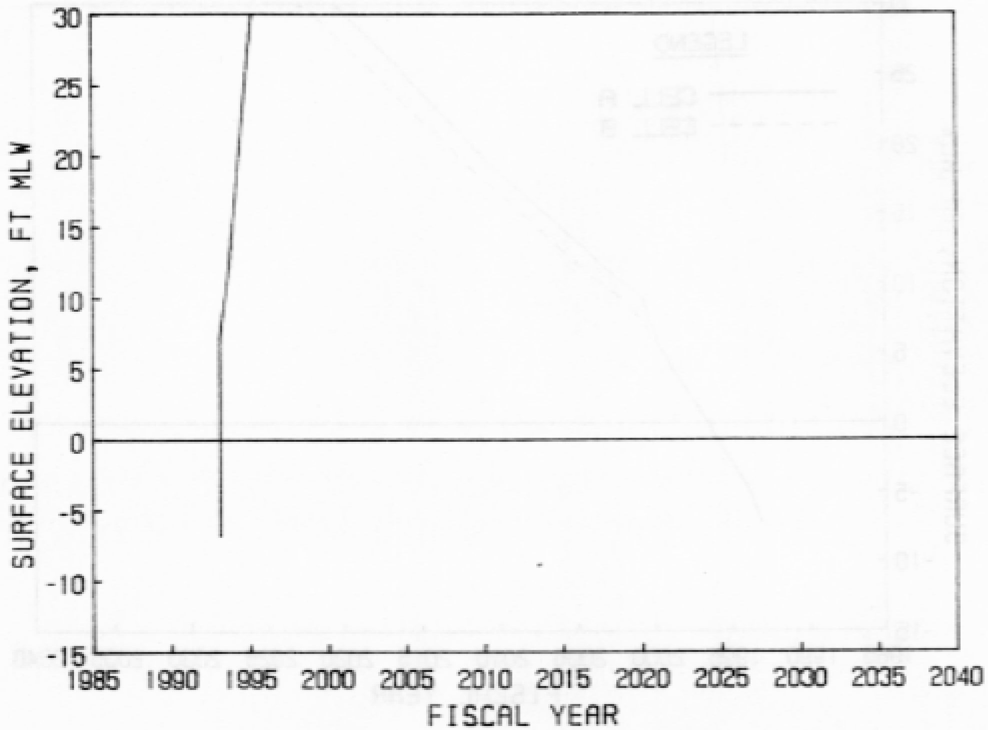

Figure C29. Expansion Alternative 4, Dredging Scenario 5

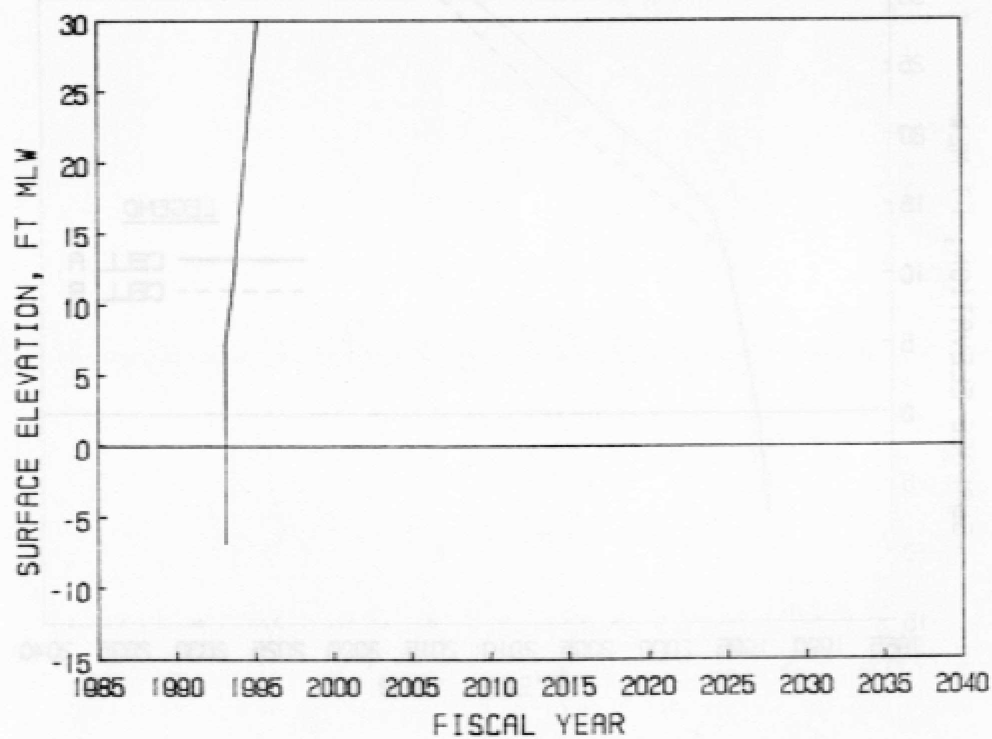

Figure C30. Expansion Alternative 4, Dredging Scenario 6

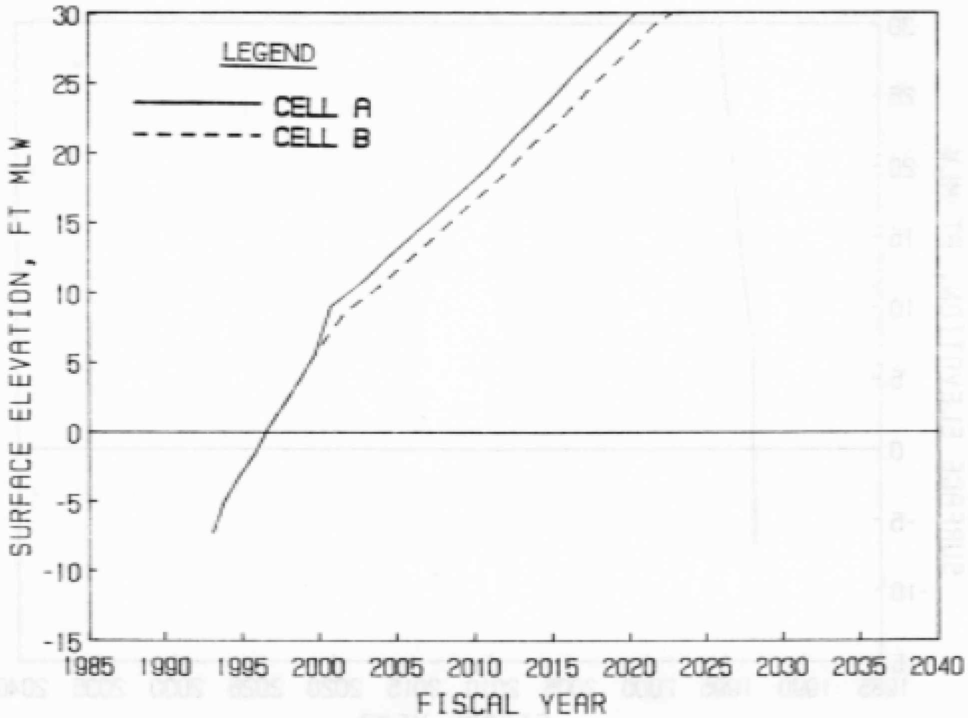

Figure C31. Expansion Alternative 5, Dredging Scenario 1

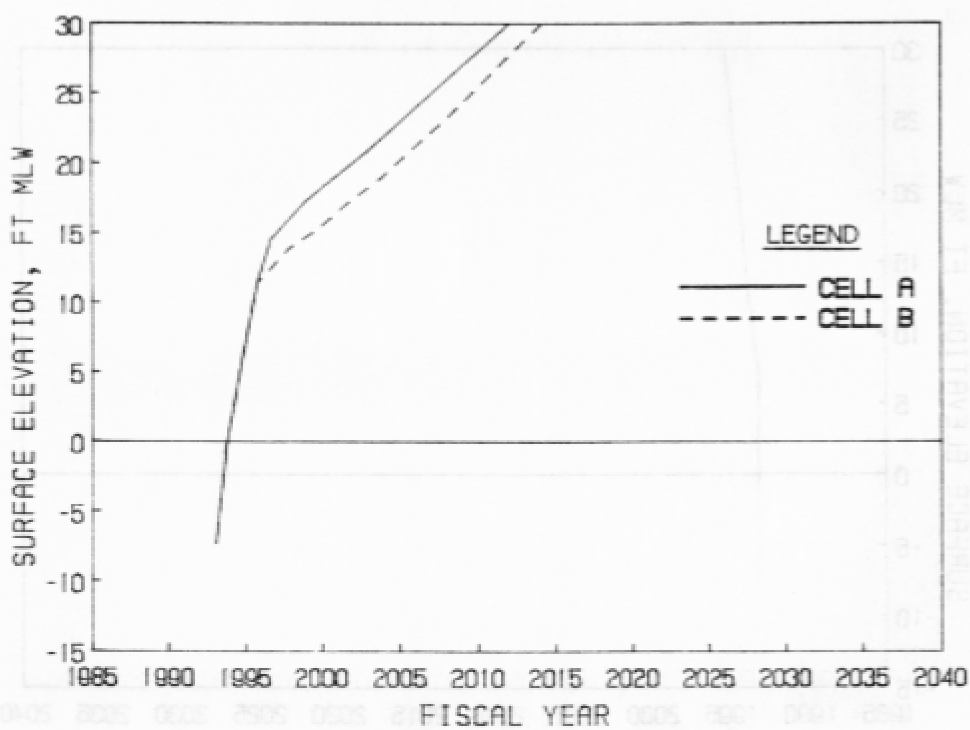

Figure C32. Expansion Alternative 5, Dredging Scenario 2

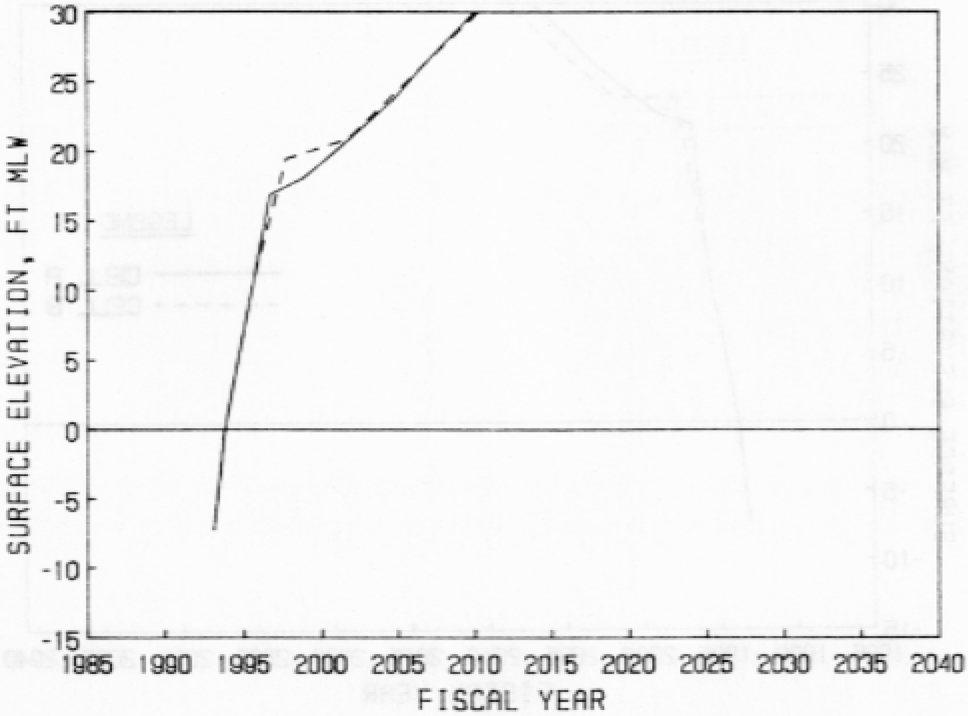

Figure C33. Expansion Alternative 5, Dredging Scenario 3

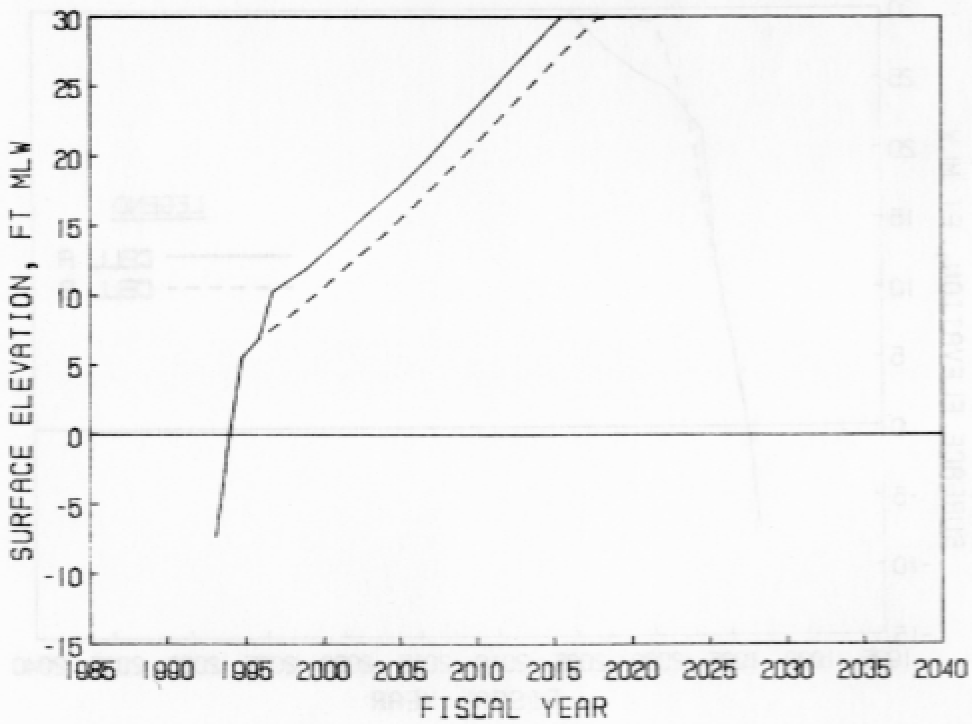

Figure C34. Expansion Alternative 5, Dredging Scenario 4

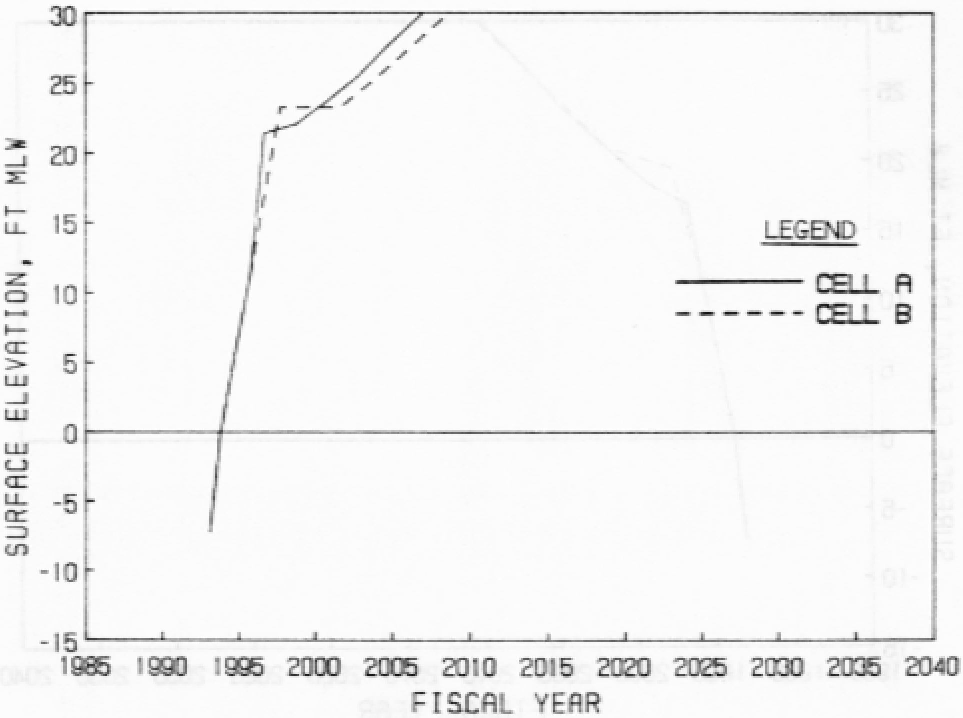

Figure C35. Expansion Alternative 5, Dredging Scenario 5

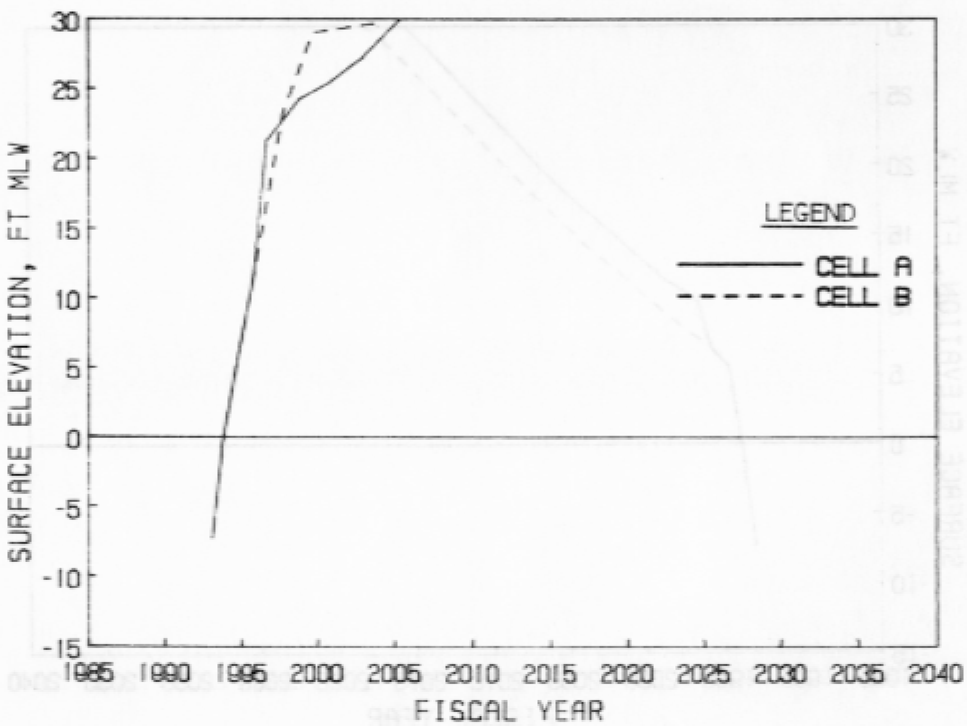

Figure C36. Expansion Alternative 5, Dredging Scenario 6

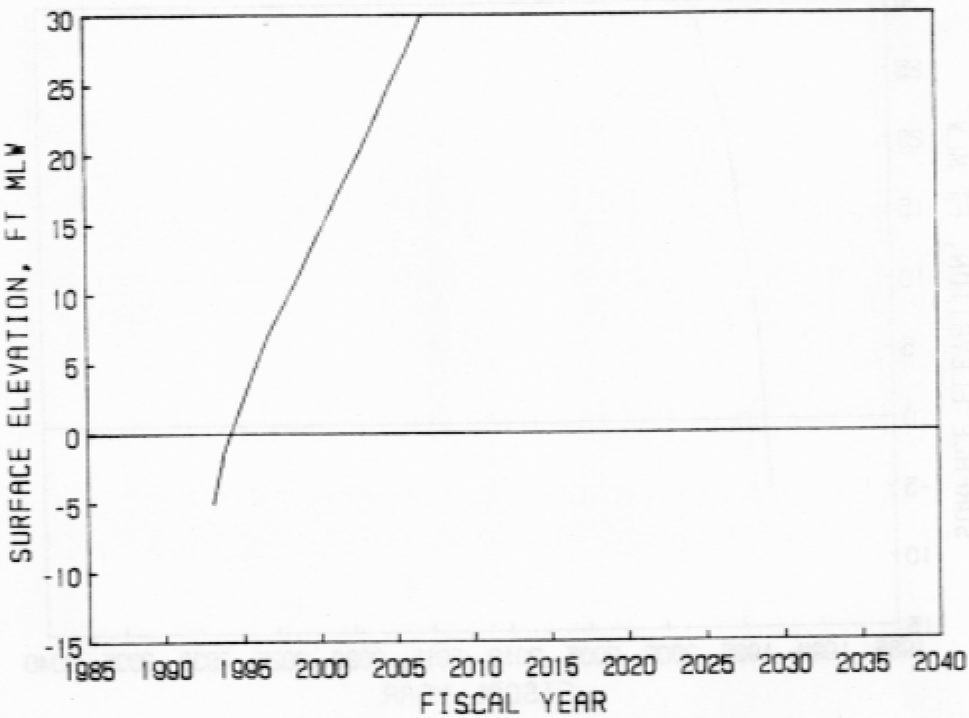

Figure C37. Expansion Alternative 6, Dredging Scenario 1

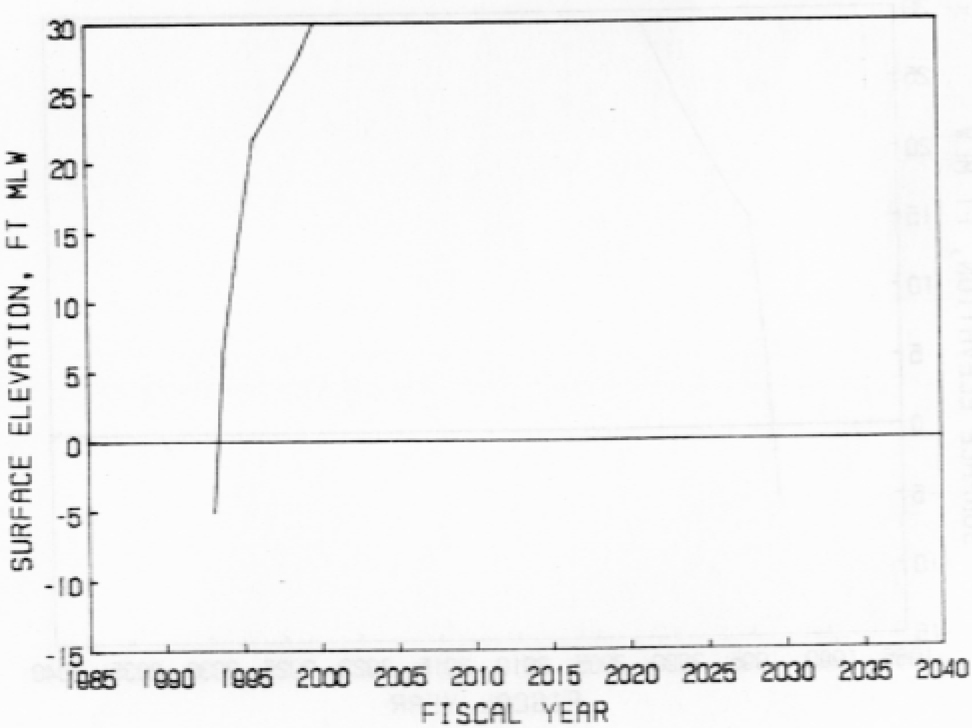

Figure C38. Expansion Alternative 6, Dredging Scenario 2

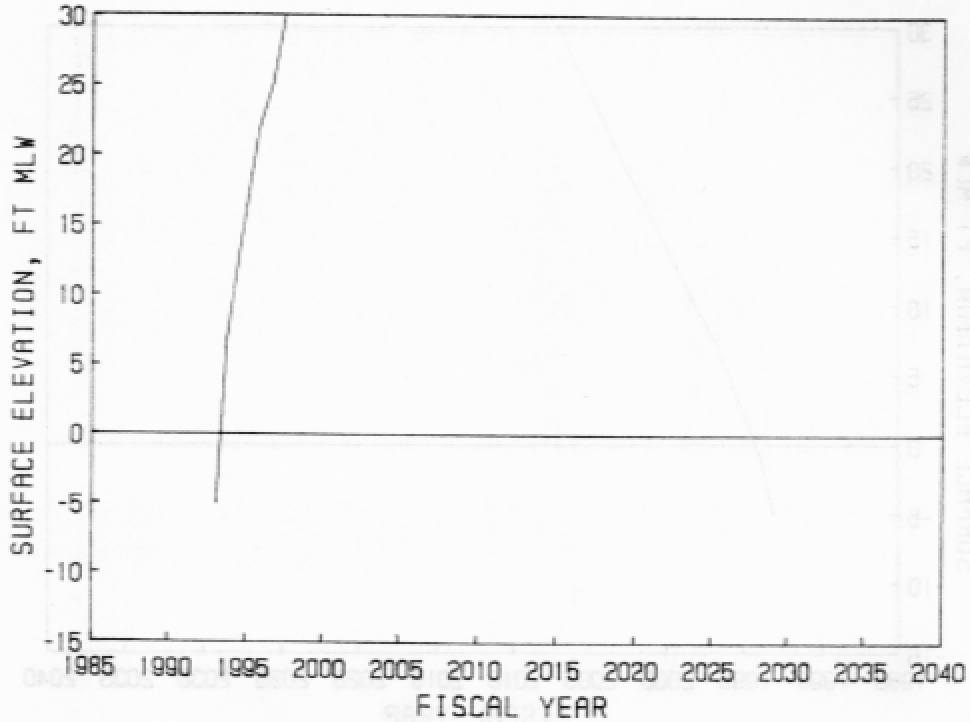

Figure C39. Expansion Alternative 6, Dredging Scenario 3

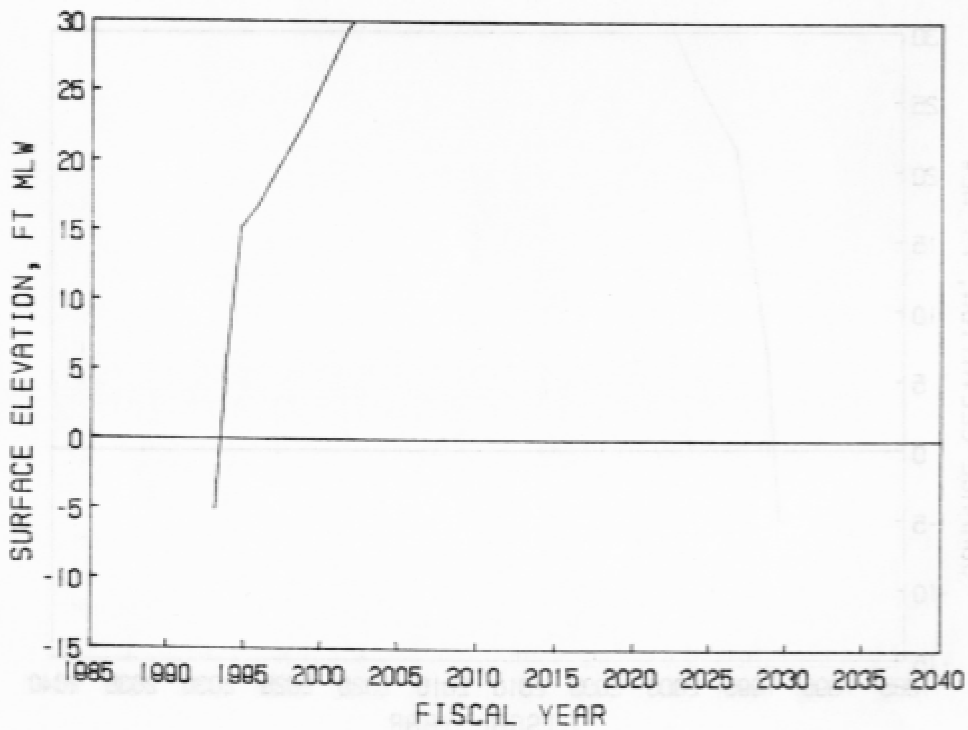

Figure C40. Expansion Alternative 6, Dredging Scenario 4

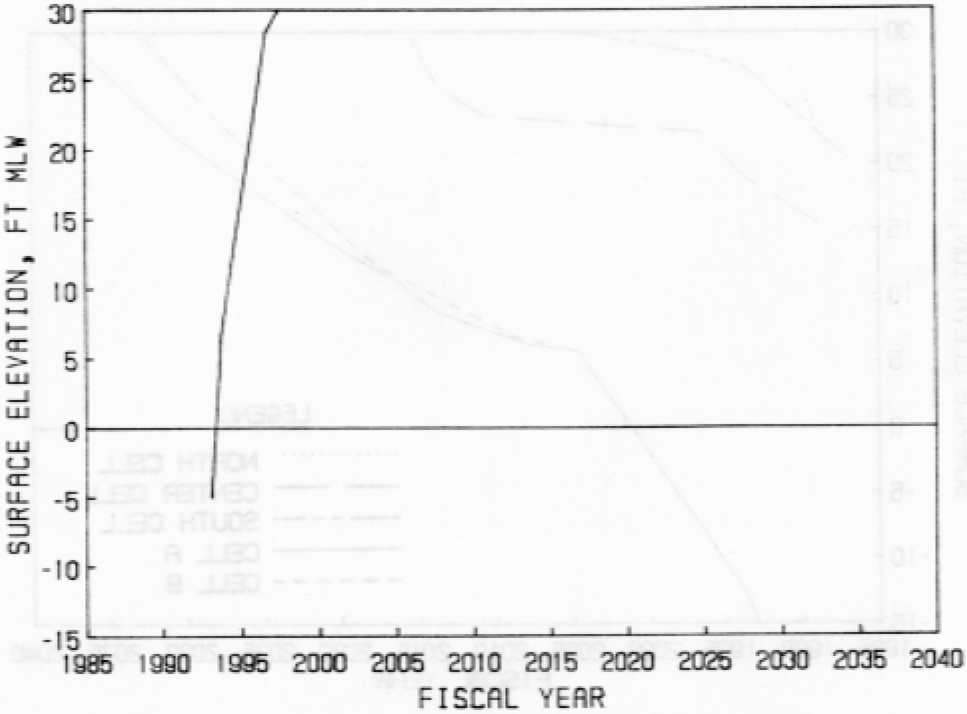

Figure C41. Expansion Alternative 6, Dredging Scenario 5

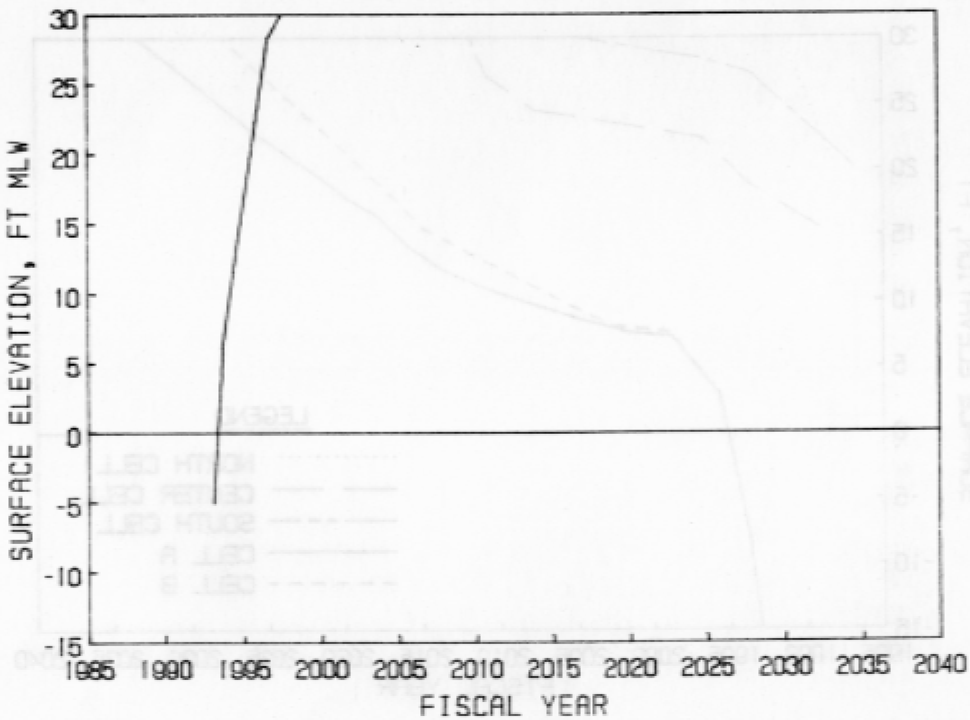

Figure C42. Expansion Alternative 6, Dredging Scenario 6

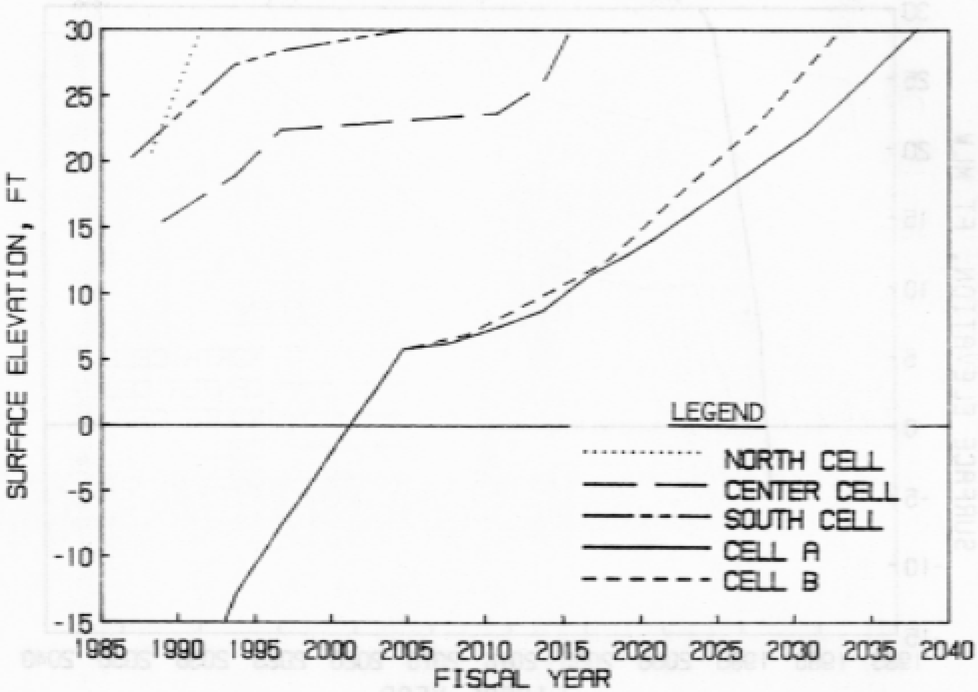

Figure C43. Expansion Alternative 1 with Craney Island, Dredging Scenario 1

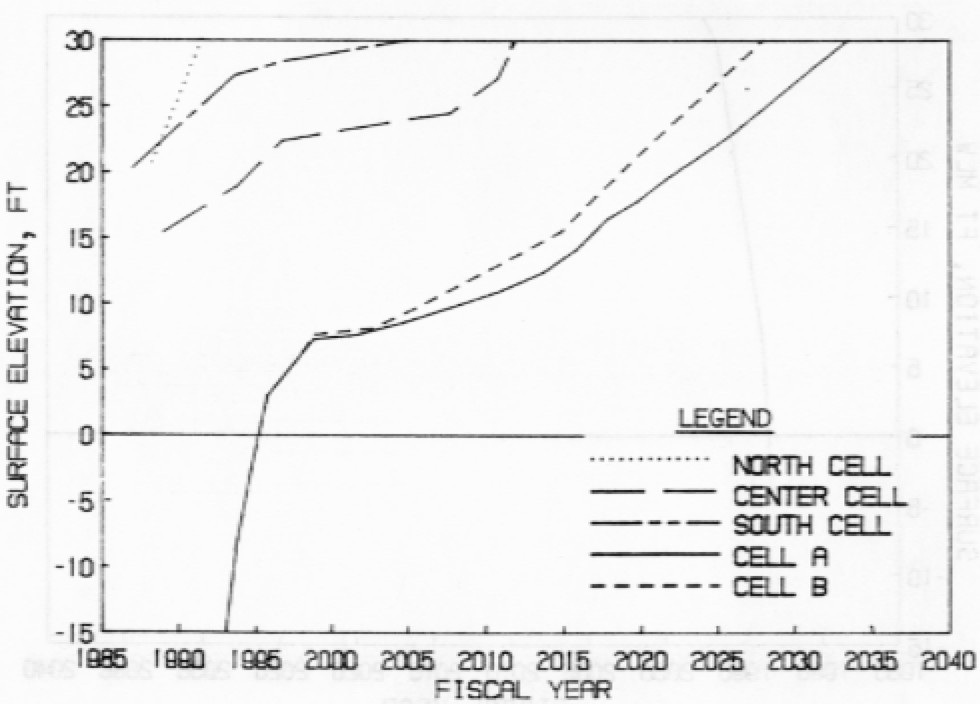

Figure C44. Expansion Alternative 1 with Craney Island, Dredging Scenario 2

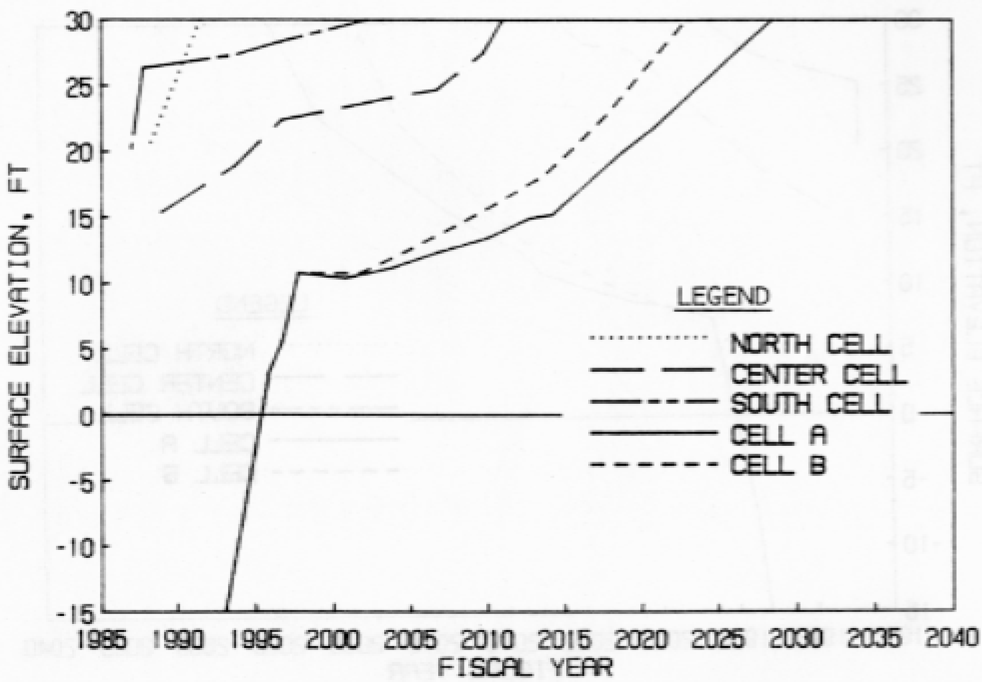

Figure C45. Expansion Alternative 1 with Craney Island, Dredging Scenario 3

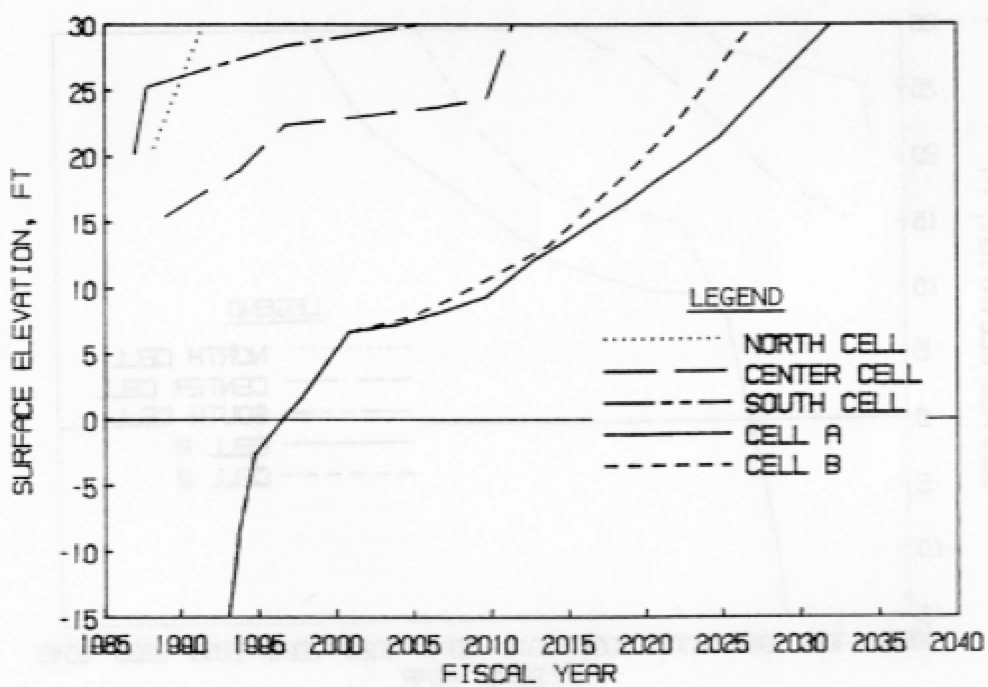

Figure C46. Expansion Alternative 1 with Craney Island, Dredging Scenario 4

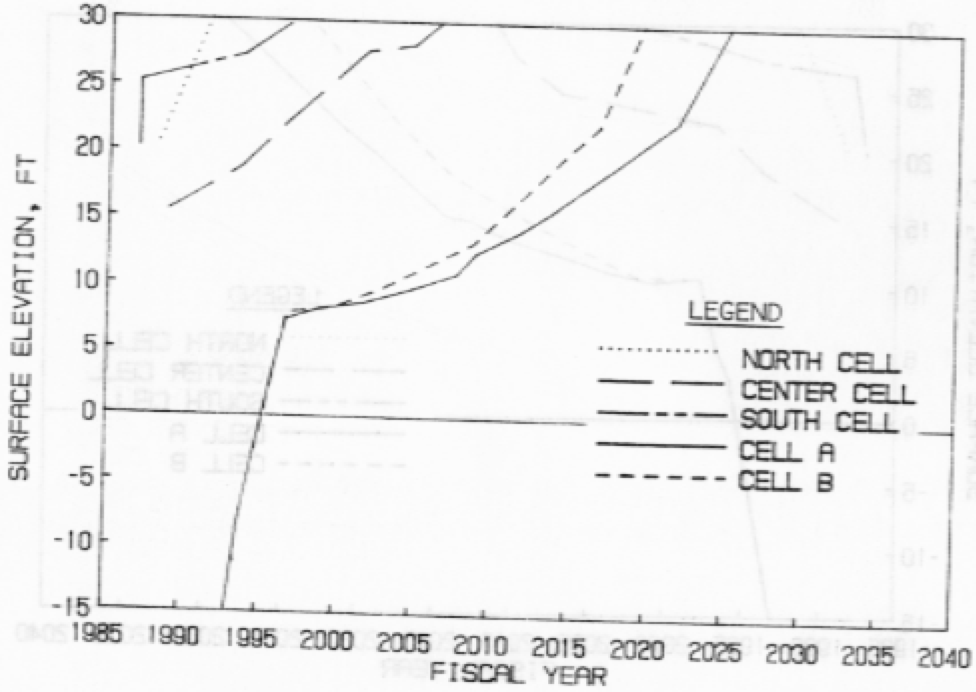

Figure C47. Expansion Alternative 1 with Craney Island, Dredging Scenario 5

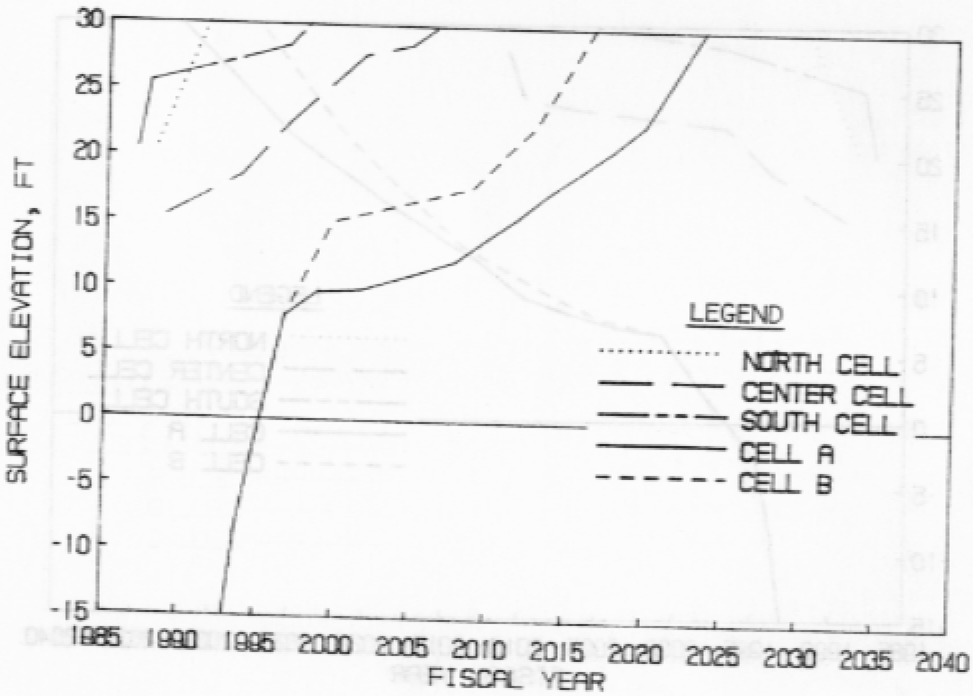

Figure C48. Expansion Alternative 1 with Craney Island, Dredging Scenario 6

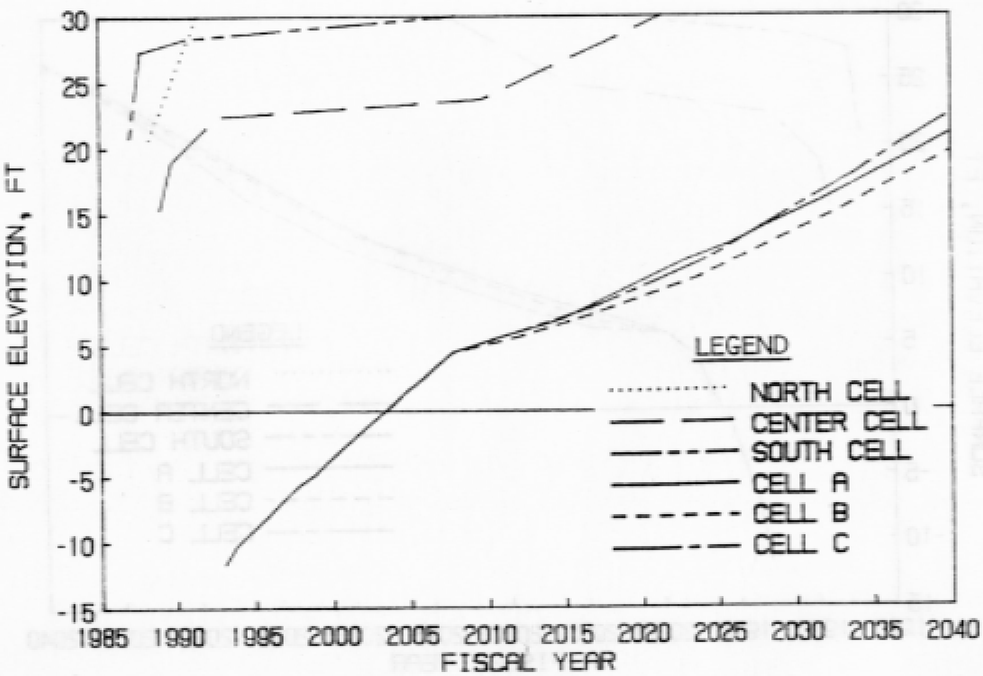

Figure C49. Expansion Alternative 2 with Craney Island, Dredging Scenario 1

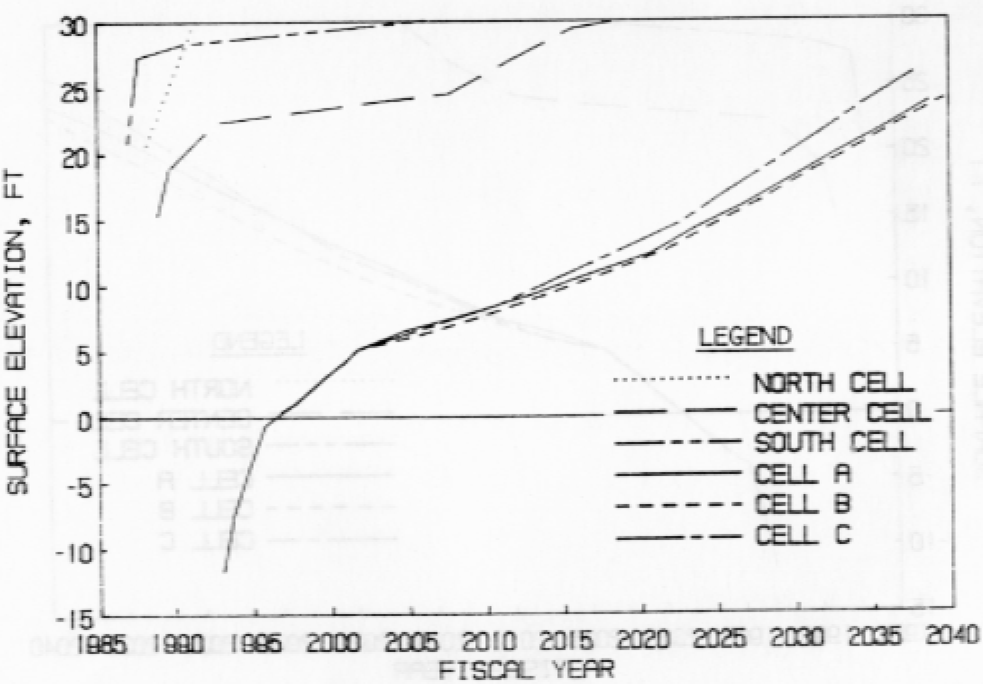

Figure C50. Expansion Alternative 2 with Craney Island, Dredging Scenario 2

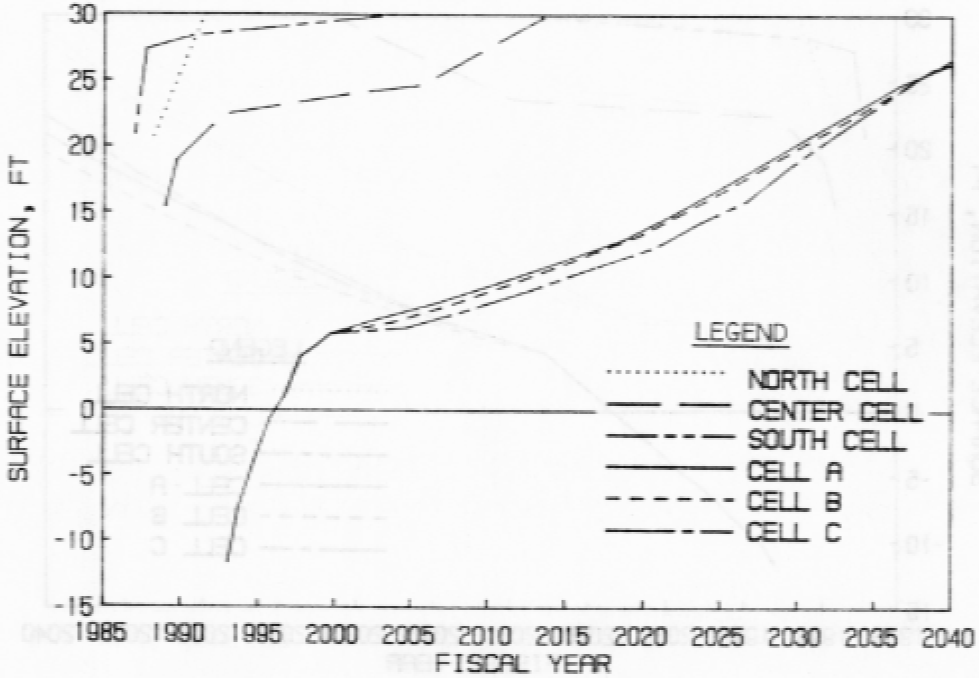

Figure C51. Expansion Alternative 2 with Craney Island, Dredging Scenario 3

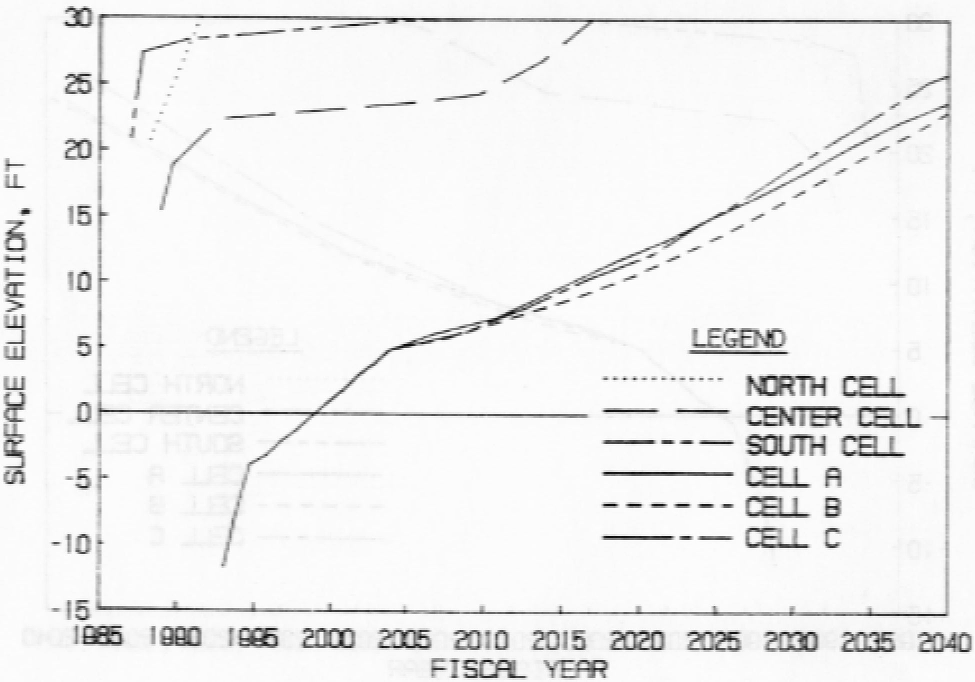

Figure C52. Expansion Alternative 2 with Craney Island, Dredging Scenario 4

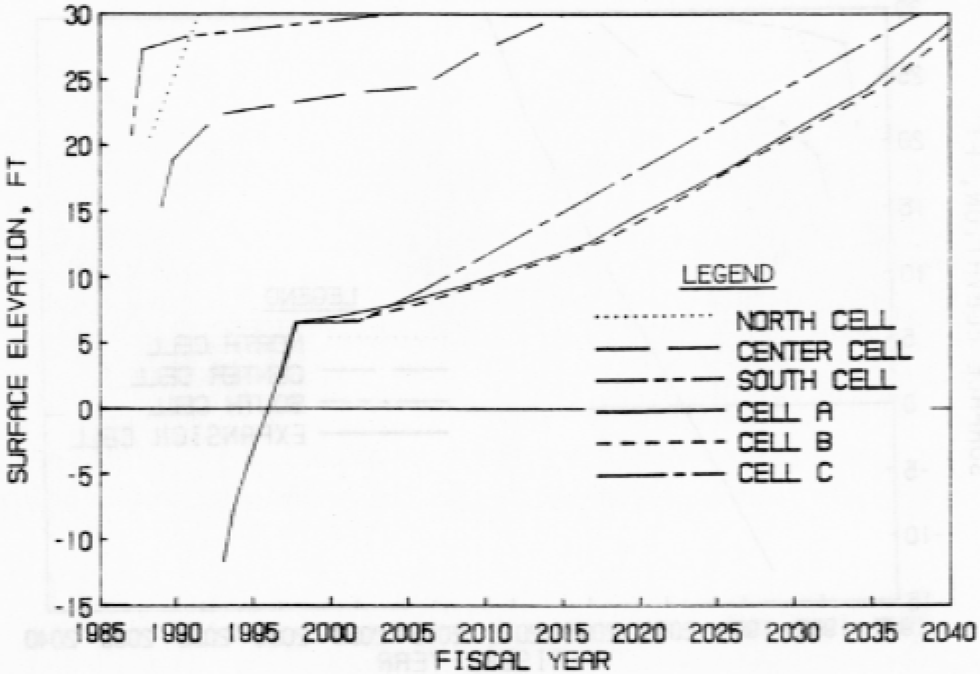

Figure C53. Expansion Alternative 2 with Craney Island, Dredging Scenario 5

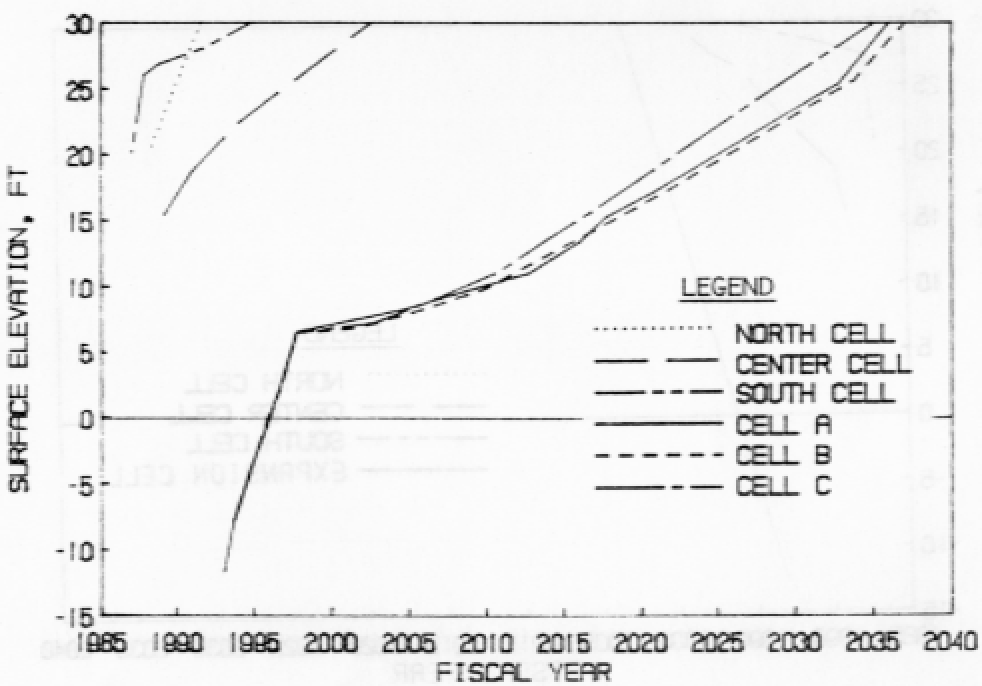

Figure C54. Expansion Alternative 2 with Craney Island, Dredging Scenario 6

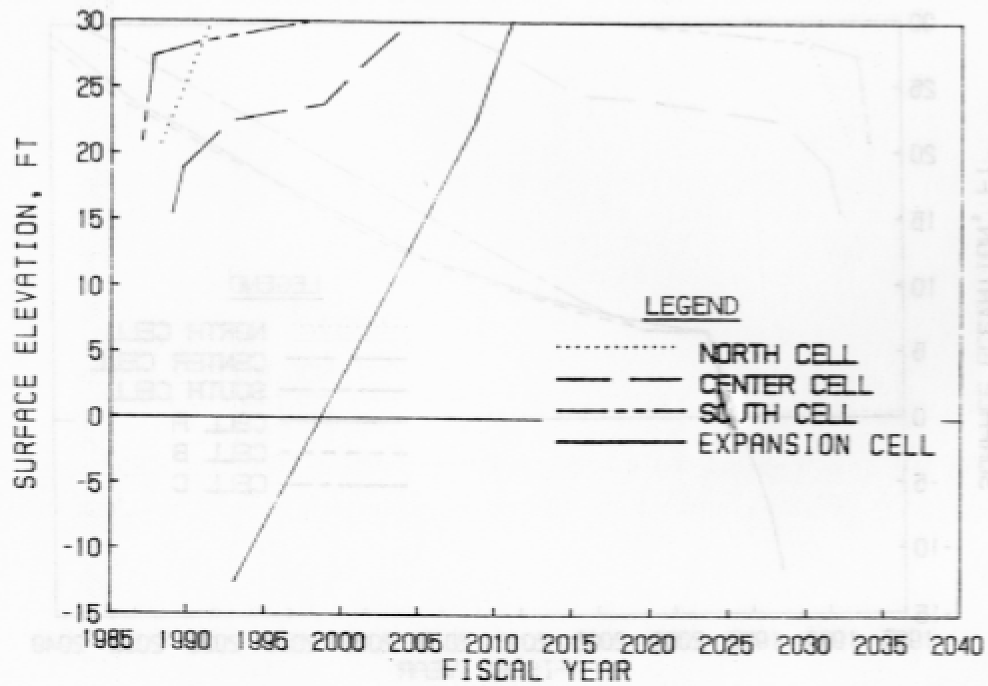

Figure C55. Expansion Alternative 3 with Craney Island, Dredging Scenario 1

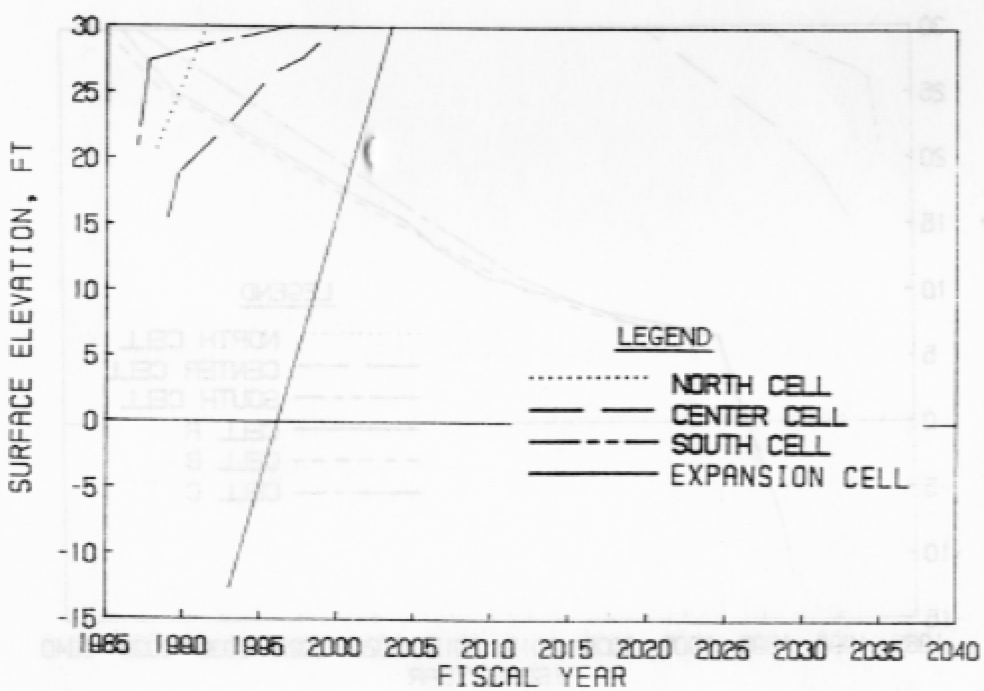

Figure C56. Expansion Alternative 3 with Craney Island, Dredging Scenario 2

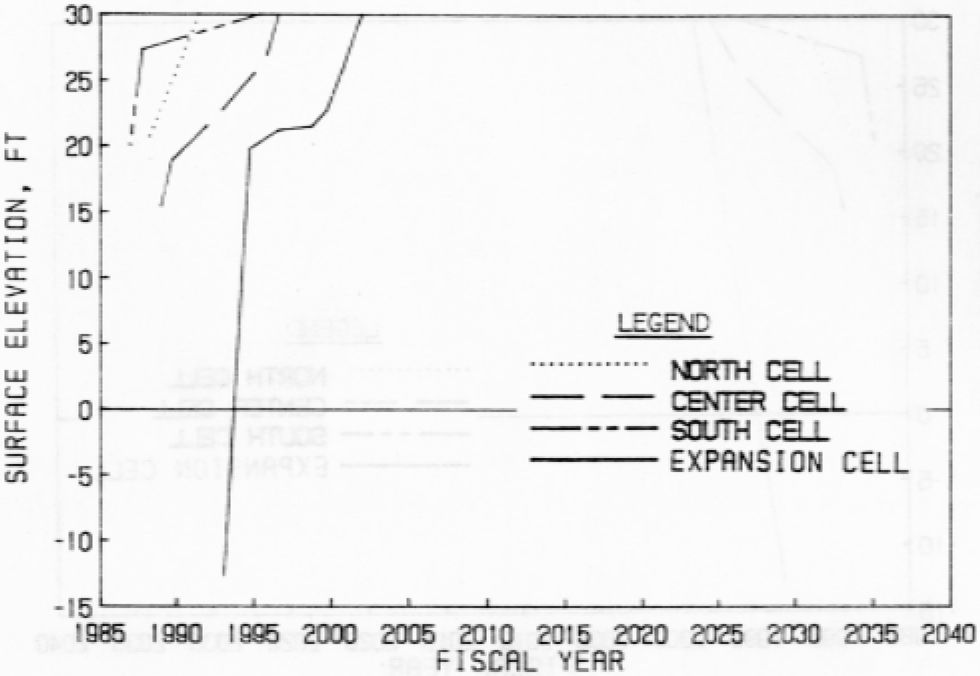

Figure C57. Expansion Alternative 3 with Craney Island, Dredging Scenario 3

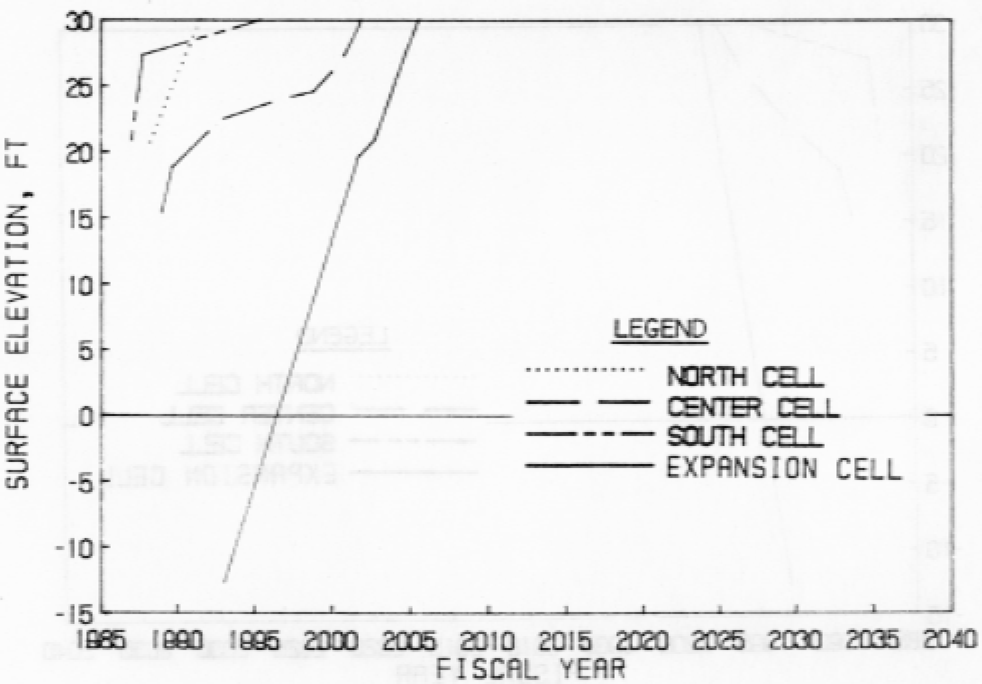

Figure C58. Expansion Alternative 3 with Craney Island, Dredging Scenario 4

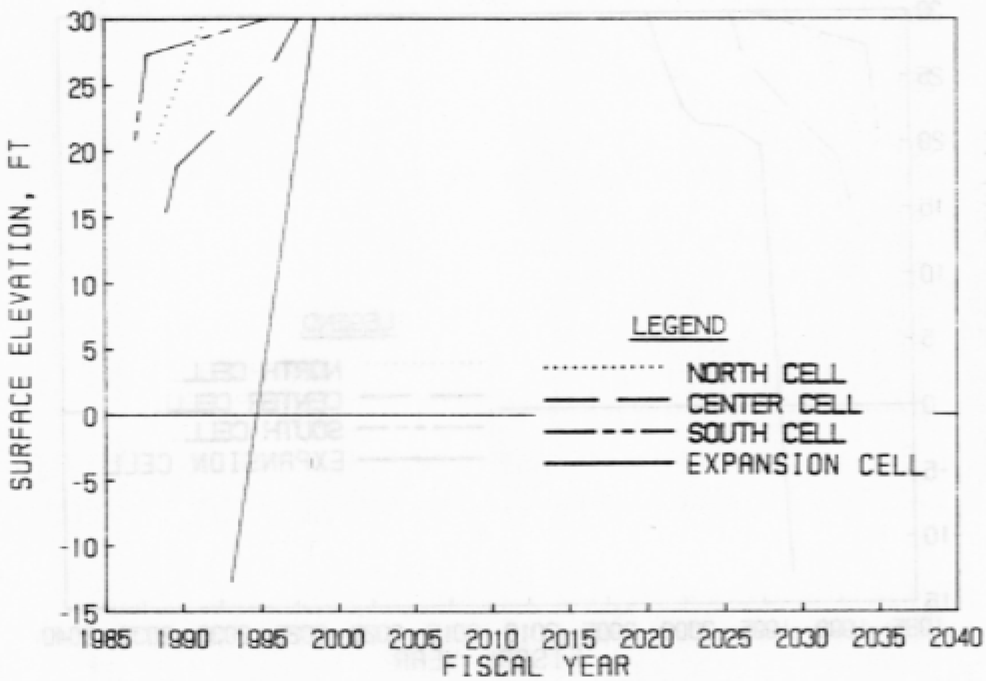

Figure C59. Expansion Alternative 3 with Craney Island, Dredging Scenario 5

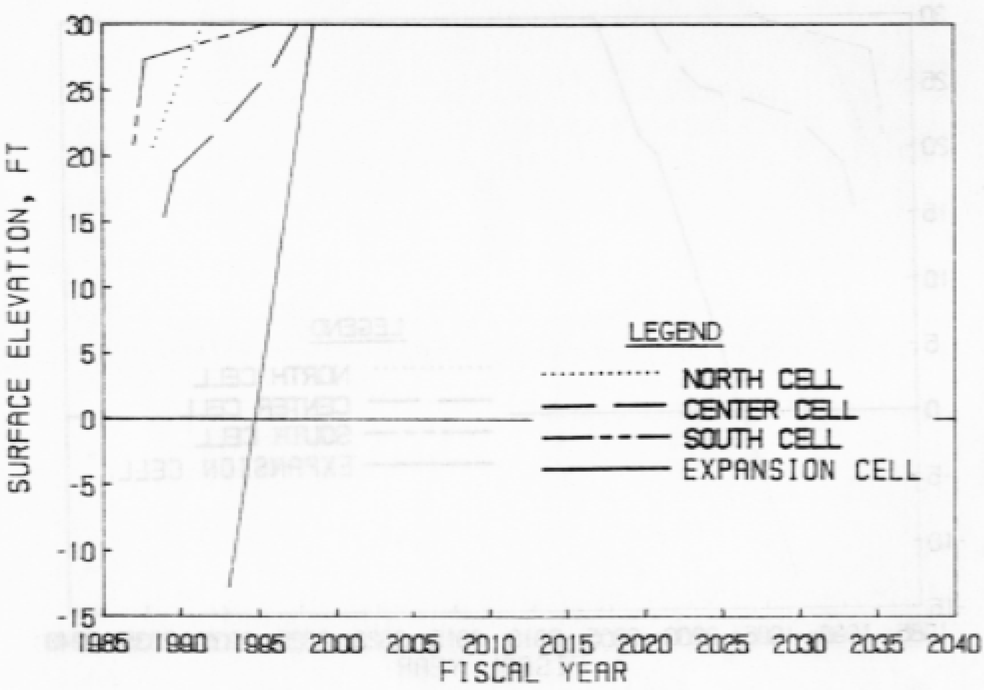

Figure C60. Expansion Alternative 3 with Craney Island, Dredging Scenario 6

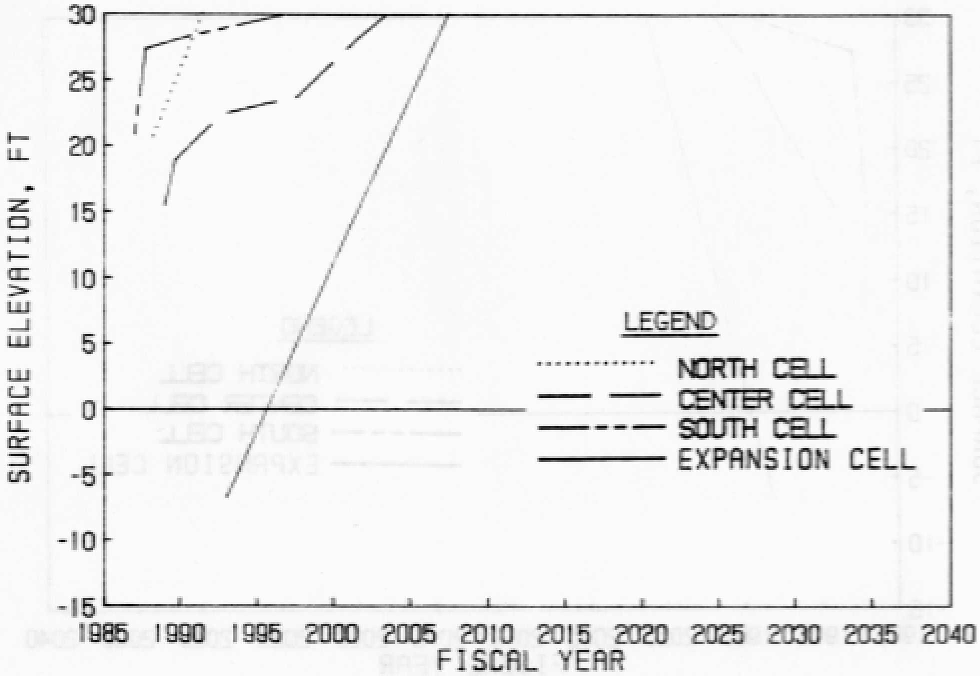

Figure C61. Expansion Alternative 4 with Craney Island, Dredging Scenario 1

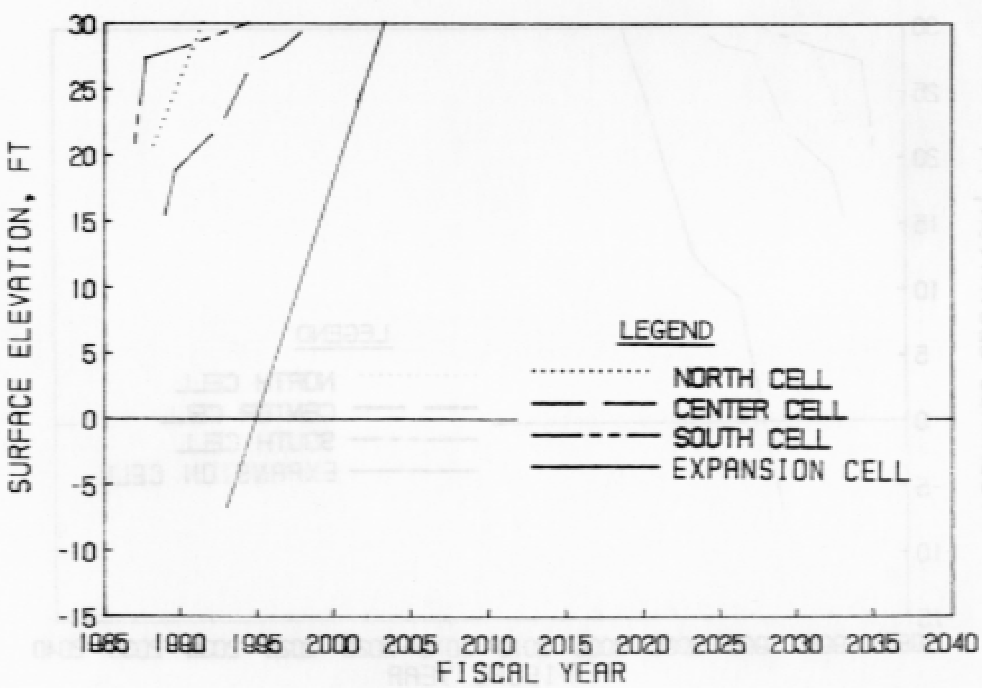

Figure C62. Expansion Alternative 4 with Craney Island, Dredging Scenario 2

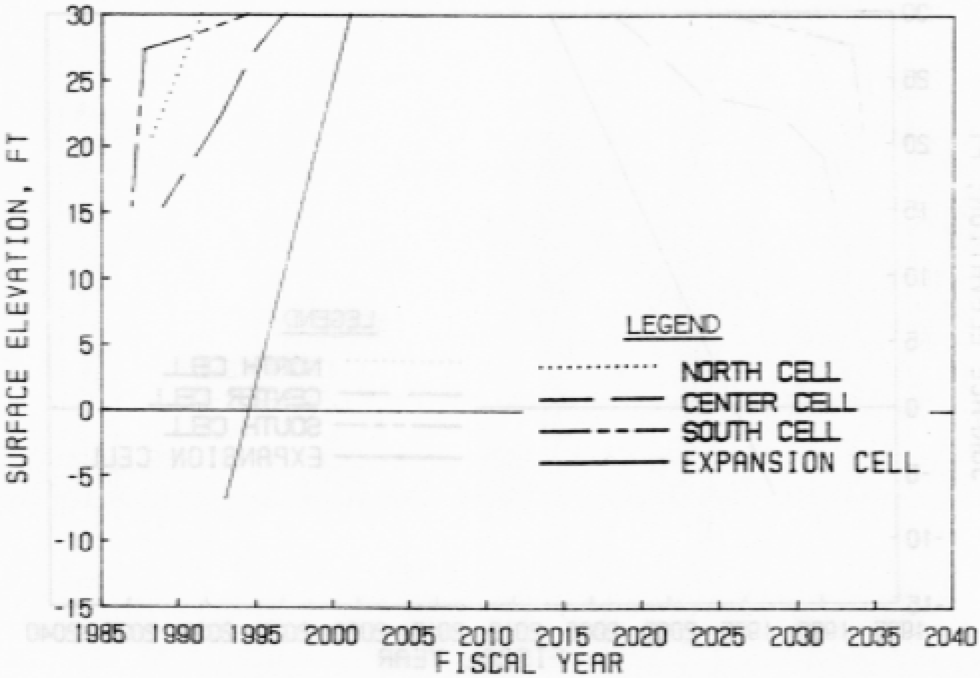

Figure C63. Expansion Alternative 4 with Craney Island, Dredging Scenario 3

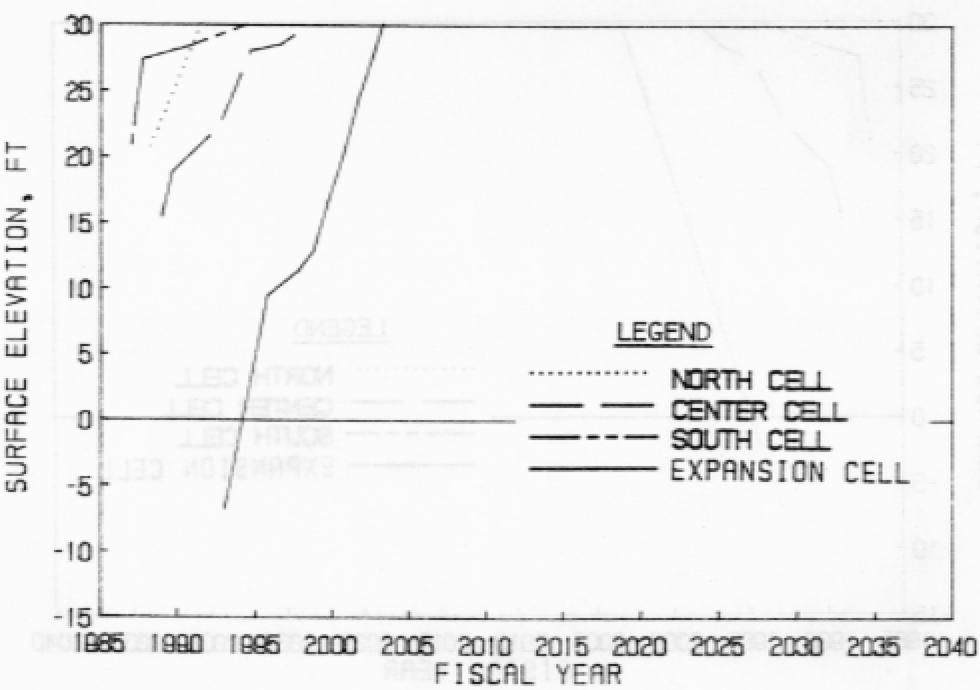

Figure C64. Expansion Alternative 4 with Craney Island, Dredging Scenario 4

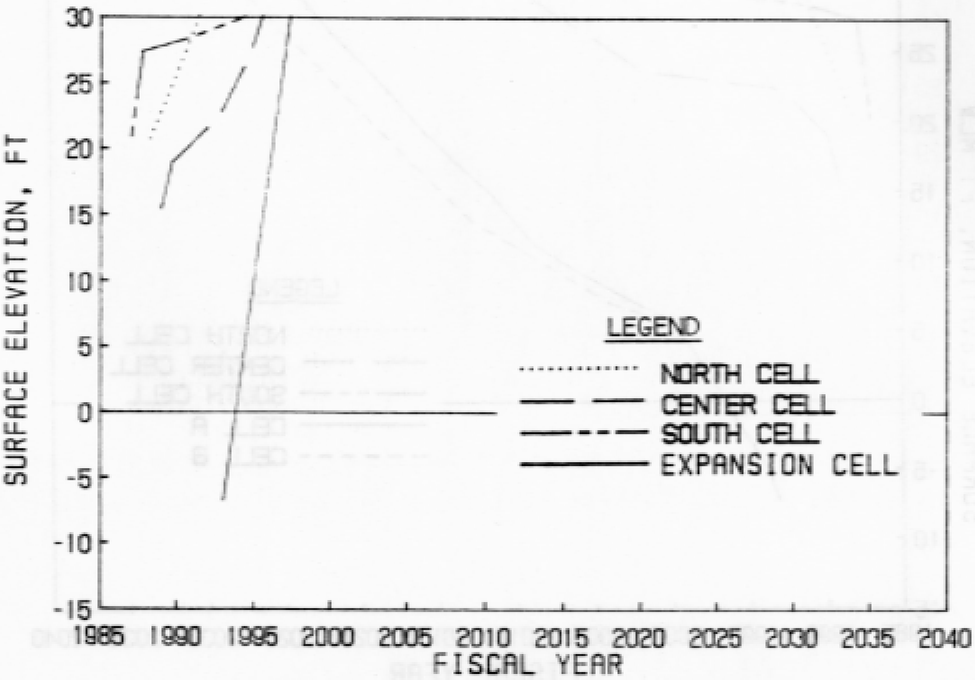

Figure C65. Expansion Alternative 4 with Craney Island, Dredging Scenario 5

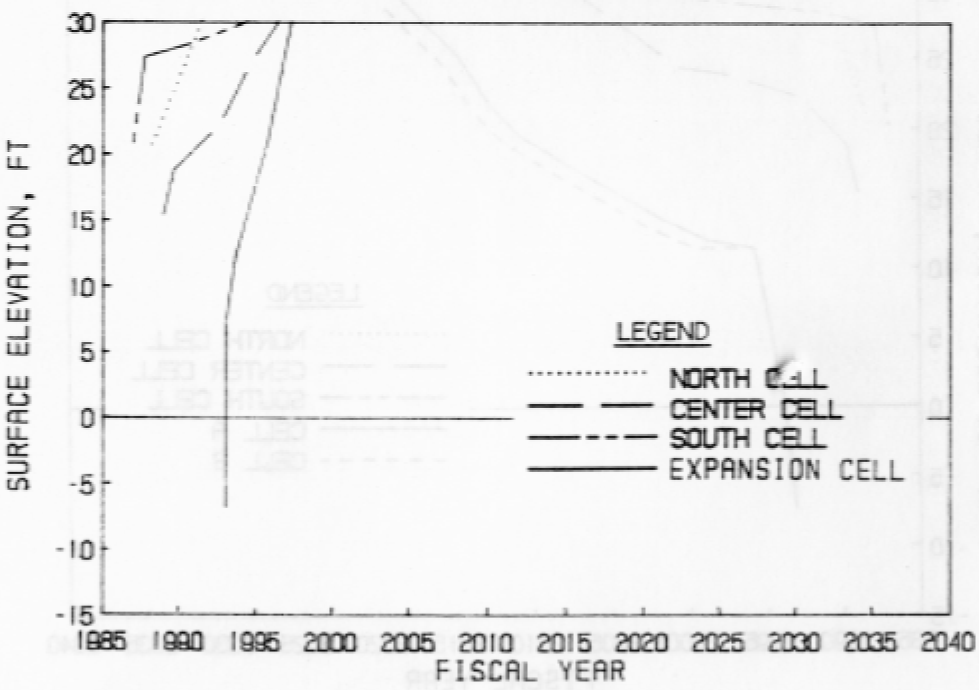

Figure C66. Expansion Alternative 4 with Craney Island, Dredging Scenario 6

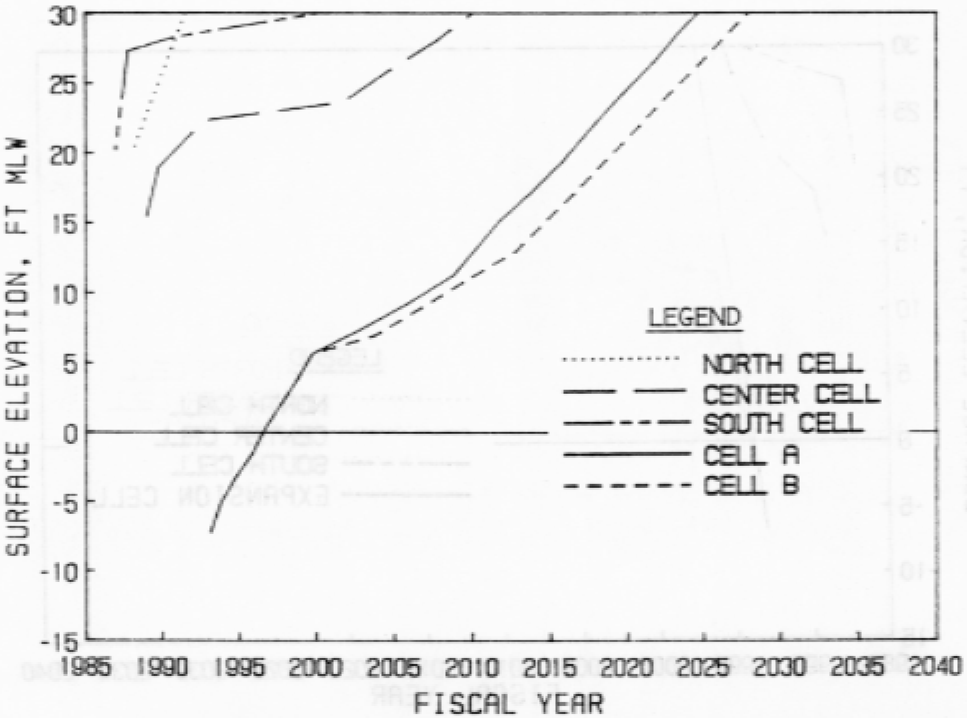

Figure C67. Expansion Alternative 5 with Craney Island, Dredging Scenario 1

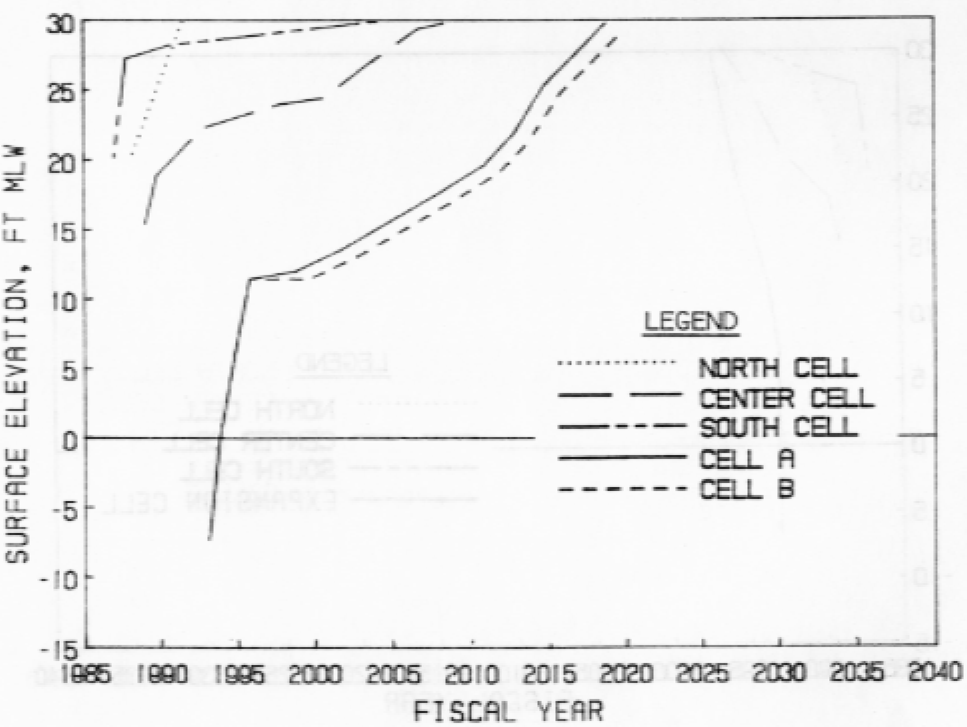

Figure C68. Expansion Alternative 5 with Craney Island, Dredging Scenario 2

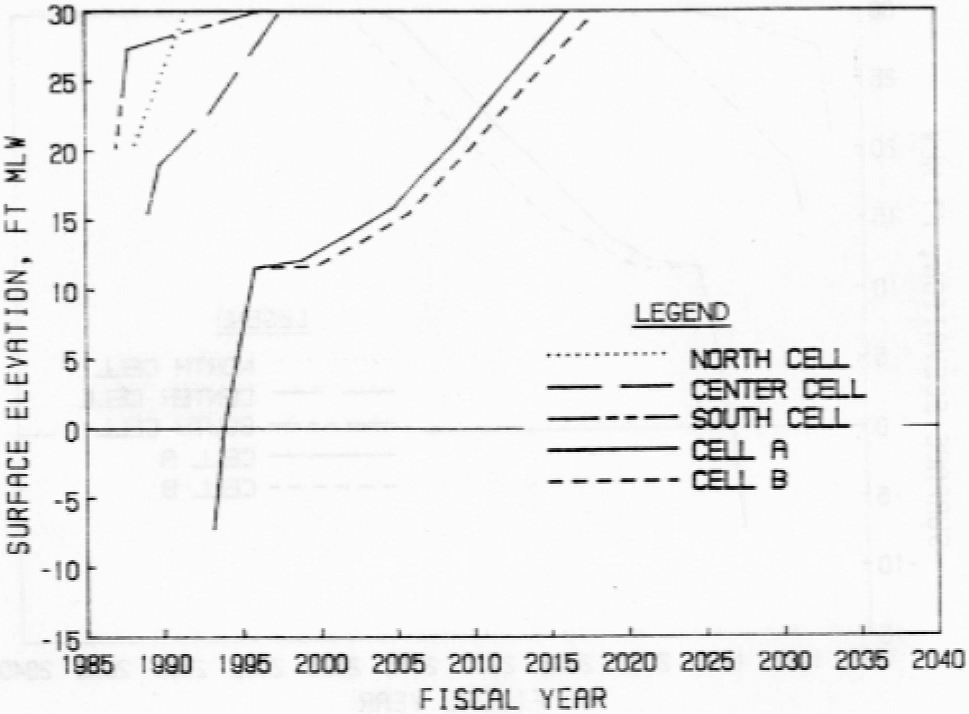

Figure C69. Expansion Alternative 5 with Craney Island, Dredging Scenario 3

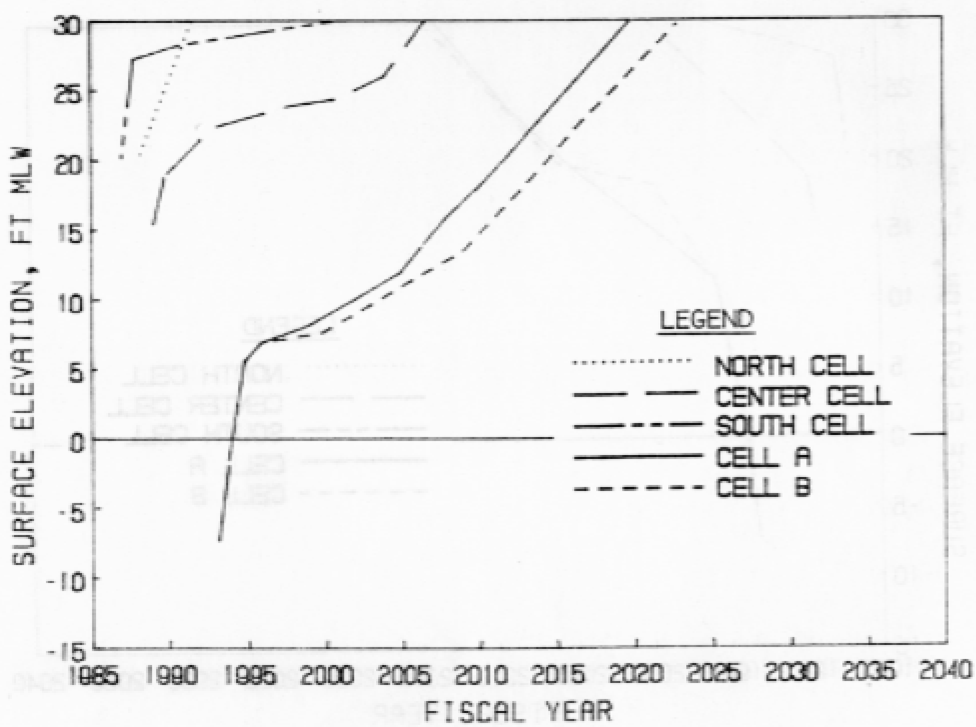

Figure C70. Expansion Alternative 5 with Craney Island, Dredging Scenario 4

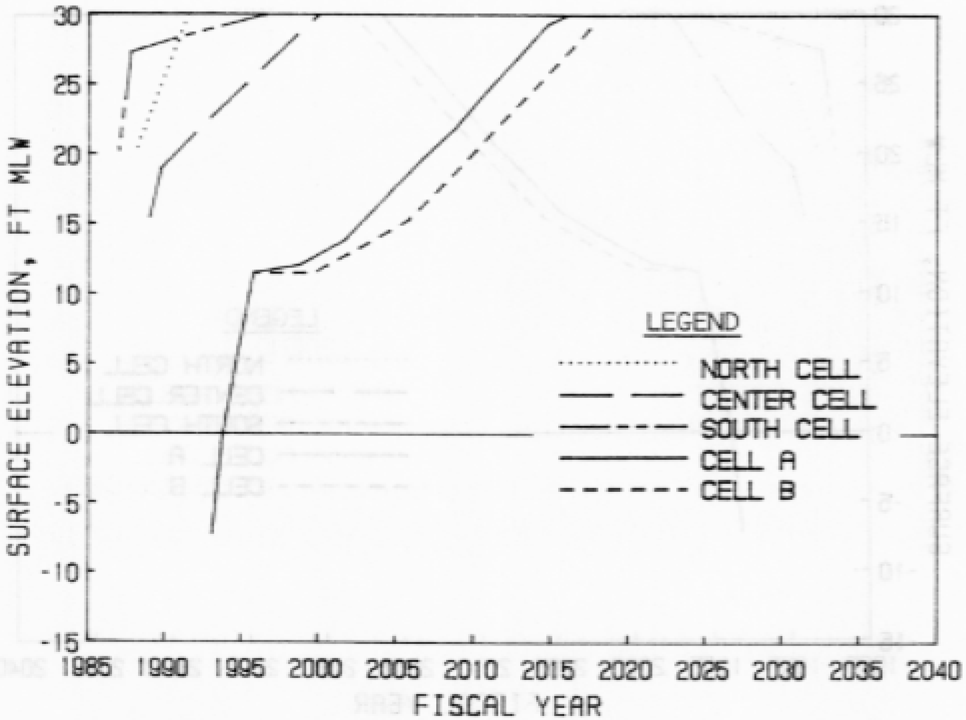

Figure C71. Expansion Alternative 5 with Craney Island, Dredging Scenario 5

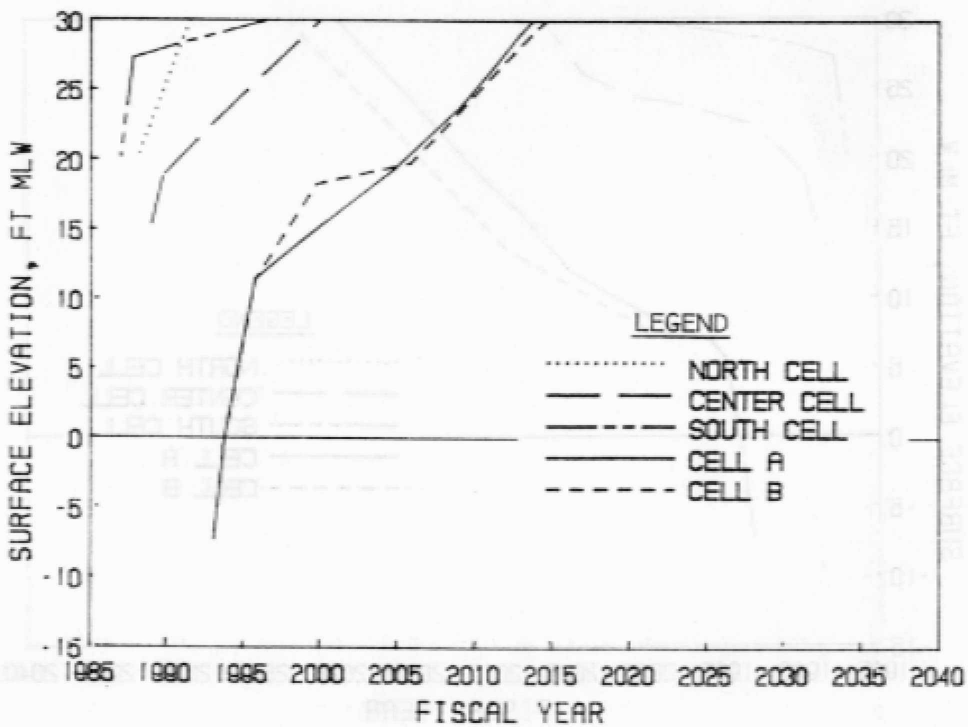

Figure C72. Expansion Alternative 5 with Craney Island, Dredging Scenario 6

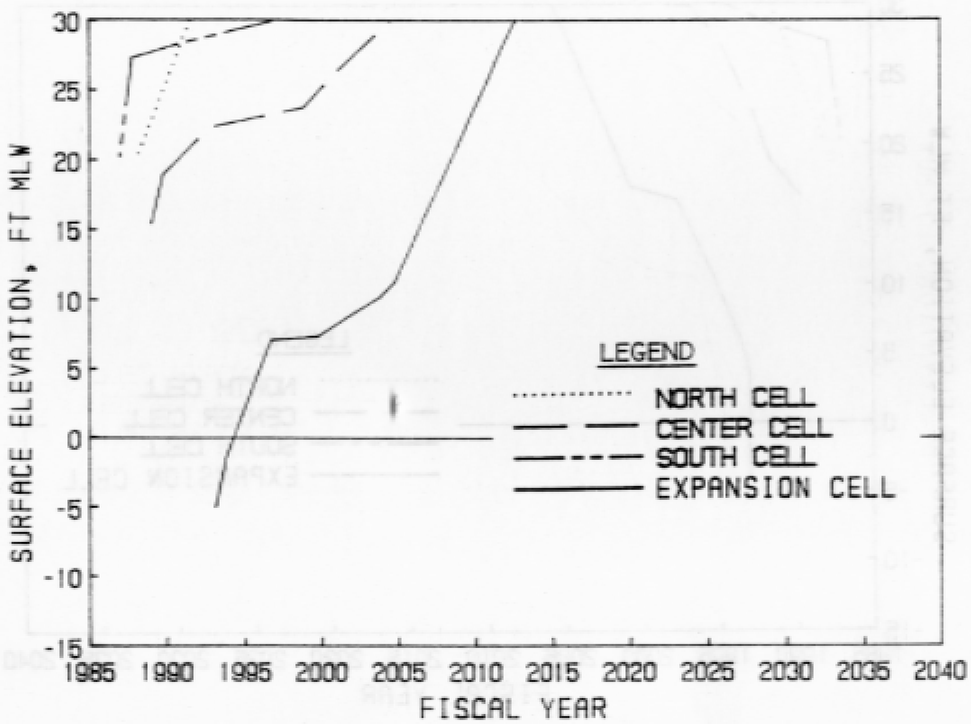

Figure C73. Expansion Alternative 6 with Craney Island, Dredging Scenario 1

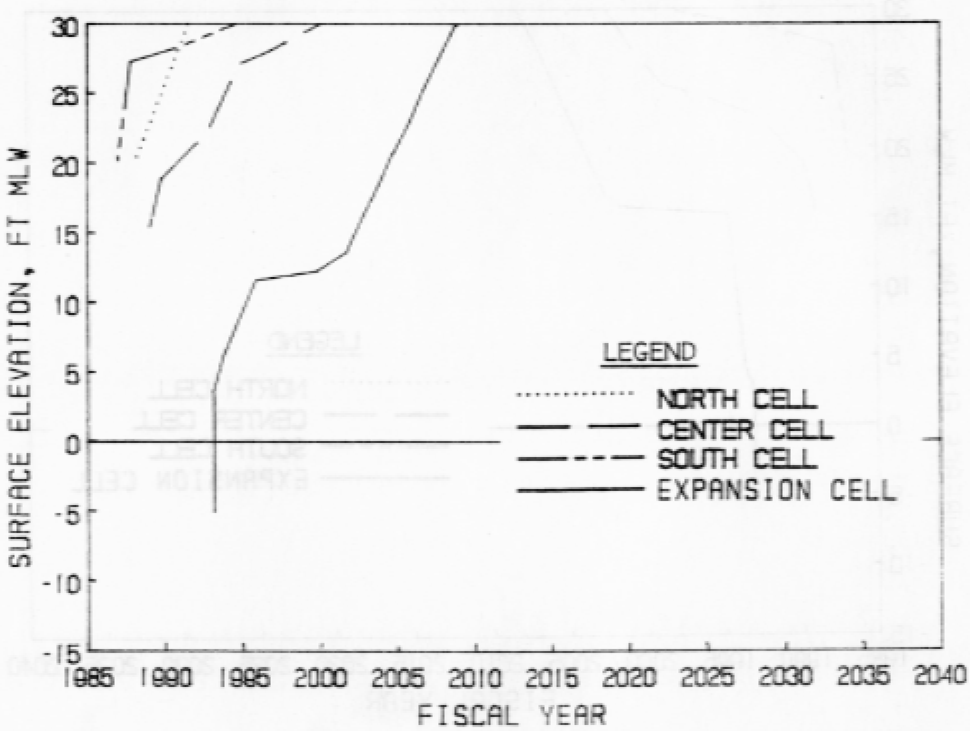

Figure C74. Expansion Alternative 6 with Craney Island, Dredging Scenario 2

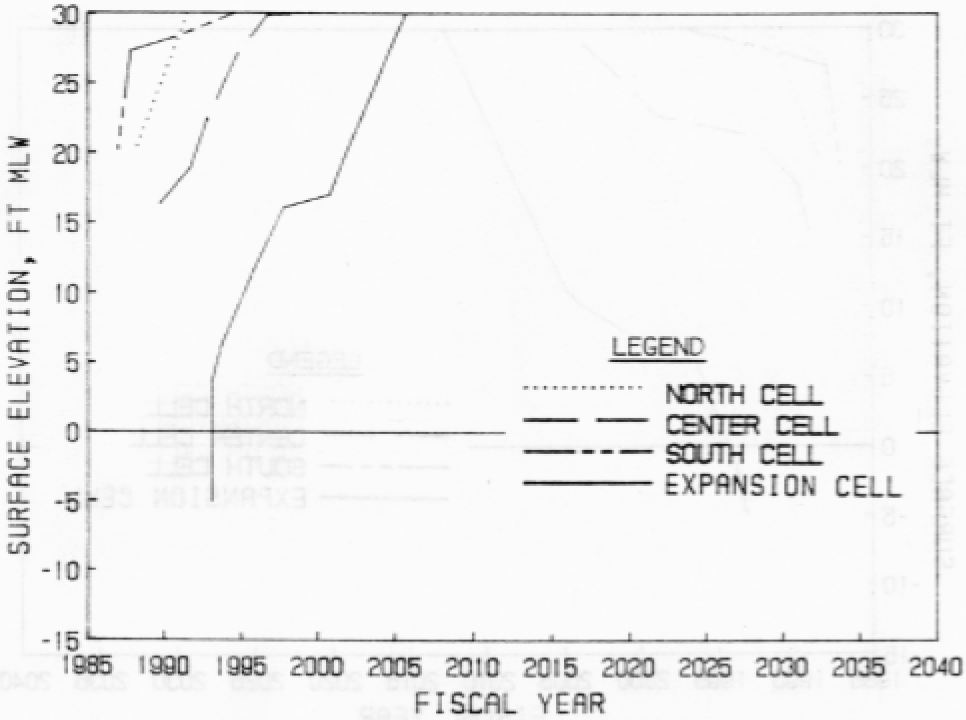

Figure C75. Expansion Alternative 6 with Craney Island, Dredging Scenario 3

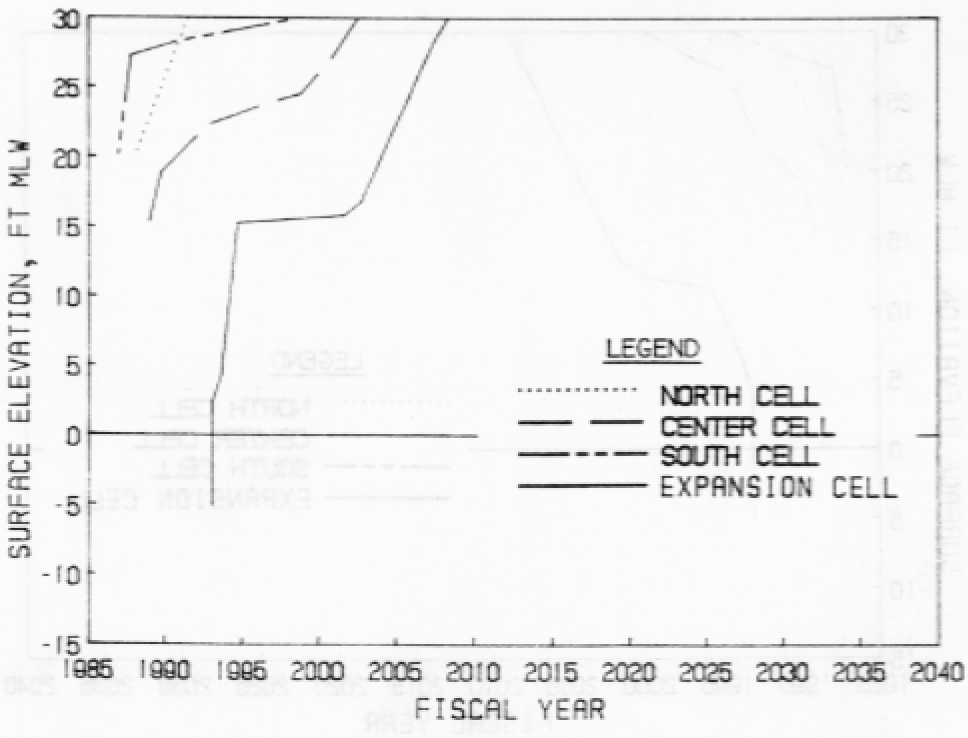

Figure C76. Expansion Alternative 6 with Craney Island, Dredging Scenario 4

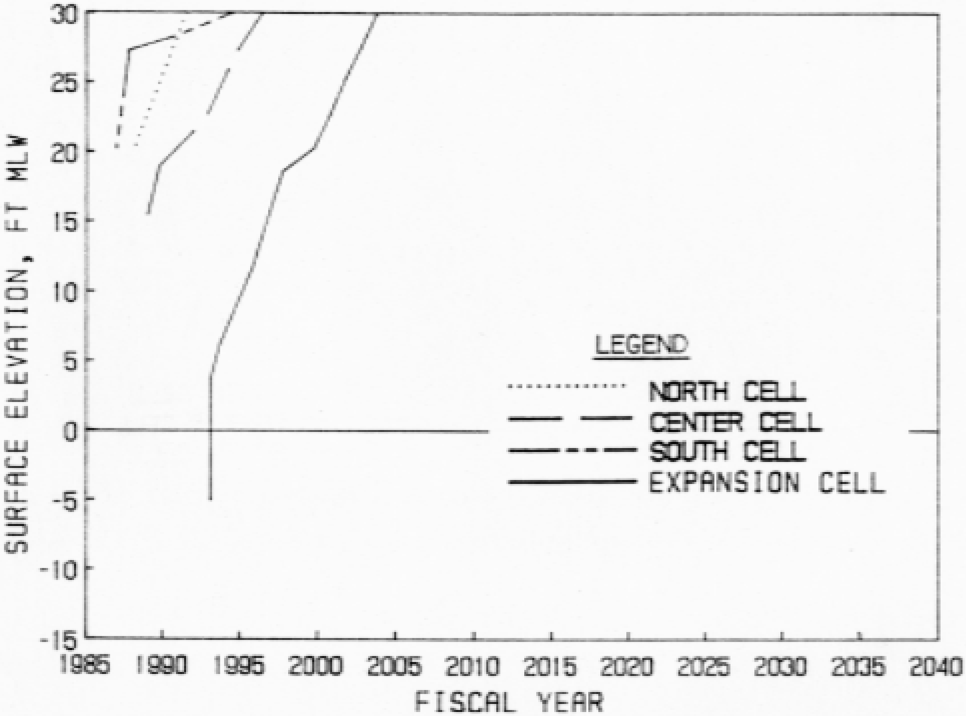

Figure C77. Expansion Alternative 6 with Craney Island, Dredging Scenario 5

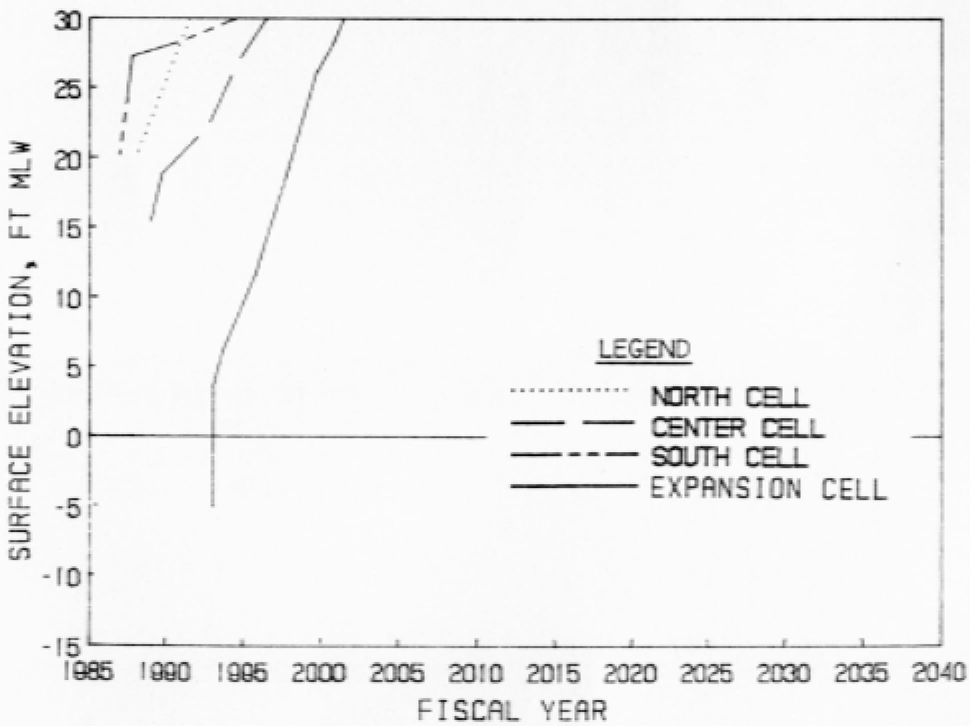

Figure C78. Expansion Alternative 6 with Craney Island, Dredging Scenario 6